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Electronic Camera

Signal Corps Mobile Television System

High-Speed Photography: Engine Research; Accuracy Limitations; Electrocardiography; Optical Aids; Rotating-Mirror Camera

Open-Air Sound Theater

Depth Effect in Motion Pictures

Screen Brightness Report

American Standards

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The Electronic Camera in Film-Making

By NORMAN COLLINS and T. C. MACNAMARA

The paper considers the cinematograph camera and assesses its inherent limitations. The advantages of multiple-camera working are discussed, with special reference to the electronic camera; the recording of an electronic image is shown to be the culminating development. The paper discusses picture quality, contrast range and tonal fidelity, and the objective and subjective evaluation of definition. The reconciliation of the electronic and photographic viewpoints is shown to be possible, and the standards of the motion-picture and television industries are compared. The paper concludes with a survey of the performance requirements of the electronic camera, the mechanics of motion-picture recording of electronic images and factors governing the choice of film stock.

(1) Introduction

UP TO THE PRESENT, the history of film-making has been virtually the history of the cinematograph camera as it was conceived by Friese-Greene and Lumière. Technical progress in design and development has been constant, but it has been in the direction of improvement and refinement rather than the establishment of new principles.

It is the intention in the paper to show why there is reason to believe that a change may be impending, and why electronic cameras, with the vastly greater measure of operational flexibility that they can offer, may supersede the purely optical camera as the basic instrument of film production.

To substantiate such a view, the consequences of which would inevitably mean the introduction of far-reaching changes in film-production technique, it is necessary first to examine the characteristics of the traditional optical-mechanical instrument and then to determine how far those characteristics have themselves governed the technique. Secondly, it is relevant to consider why any instrument possessing what, in the view of the authors, are inherent limitations in its application should for so long have been accepted as the standard apparatus of the industry.

It is not suggested that the modern

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cinematograph camera bears more than superficial filial resemblance to the "magic boxes" of film-history. Indeed, the current models of orthodox equipment are elaborate instruments built to precision-engineering standards and modified in every detail by half a century of operational experience. In the result, there has been evolved a piece of apparatus of known and highly efficient optical characteristics, proved reliability in performance and general simplicity of maintenance.

Nevertheless, its basic principles remain unaltered. It persists as essentially an instrument to record a sufficiently rapid succession of single images of successive stages of movement within the framework of a single scene for the eye to be deceived by the illusion of continuous movement when the recorded images are subsequently projected. If a visual succession showing two different views of the same scene (as in a "cut" from a medium shot to a close-up), or two views of entirely different scenes (as in a cut from an interior to an exterior), is required the camera must occupy two different shooting positions, and the resultant film recordings must be joined together before the effect of the visual succession can be artistically evaluated. Furthermore, if the image of one scene is to be superimposed upon another (as in a "mix") it is necessary to go beyond the resources of the camera altogether and make use of the additional optical processes of the laboratory. In short, the single optical camera by its nature has to be assisted artificially before it can provide the multiplicity of recorded impressions from different viewpoints that the modern entertainment film requires.

Moreover, by its nature the optical camera is secretive in operation and reticent about its viewpoint until the exposed film has been developed. At most the camera shares its view with the camera operator; others — the director, for instance — may examine the scene in the view-finder before "shooting" begins, but in the result the utmost that can then be said with confidence is that the image appeared thus at the time of the examination and is not by any means how the image will necessarily appear when the camera actually begins operation. The significance of this should not be overlooked, for it means that, at the moment of shooting, the director is inevitably excluded; he becomes, as it were, an onlooker.

It is not, indeed, until after the development and projection of the "rushes" that the director is in any position to know whether or not he has achieved the original artistic purpose which lay behind the "shot." And it is because of this inability to pronounce judgment at the time that the prudent director often covers his misgivings by one or more "re-takes," in order to ensure that some part of the exposed film depicts the action as he wishes it.

It is sometimes argued that the unavoidable period of waiting before being able to study the projected film is not injurious to the end-product but is, in fact, positively beneficial. The view has been expressed that the technical perfection of the finished film can be obtained only by these two distinct processes — the totally undistracted shooting of individual and unrelated scenes in the studio, followed by the far more leisurely assessment of the "rushes" when they are projected upon the screen in the viewing theatre.

Such a view may well rest upon a confusion of cause and effect, and may indeed conceal a misconception of proper artistic method, for it can be argued that, with the facilities offered by the present type of camera, no other procedure could possibly be employed.

It now becomes profitable to consider the relationship of the individual shots to each other. It will be accepted by most film-makers that a great — possibly the greater — part of the artistic merit of the finished film, i.e. its effect upon the audience, will ultimately depend as much upon the juxtaposition of sequences as

upon the merits of the individual shots themselves.

In film-making under present conditions, however, the director is denied the possibility of any prior judgment on this point. He is compelled to rely upon "assembly" or "rough-cut" of the rushes before he can begin to evaluate these juxtapositions properly. By then it is frequently too late, except at considerable expense, to add what is discovered to be missing or to put right what is found to be wrong; furthermore, it is not until this stage that it can be realized that certain shots which are satisfactory in themselves are nevertheless redundant.

Nor is it surprising that this state of affairs should be so; because of the nature of the medium in which he is working, the director is in the position of an artist denied the facility of sketching-in the general outline of his picture and therefore forced to bring the various details to perfection as he proceeds. It should be recognized that the only outline to which the director can refer is his shooting script. This can, however, prove a false and misleading guide, inasmuch as the whole art of film-making consists of the translation of a literary form into a visual one, and it is only visually that the finished result can be judged.

(2) The Technique of the Electronic Camera

The use of the electronic camera — or rather a unit of three or four such cameras — will obviate many if not all of the difficulties which confront the film director who is employing single optical equipment. It is of the essence of the electronic method employing more than one camera that, during both rehearsal and shooting, the director can view upon his monitor screen not merely isolated shots but complete sequences (i.e. the blended output of his several cameras) of whatever length he may desire. The director can thus study the "architecture" of the film whilst the construction of the whole is still being composed, and the element of artistic hazard intrinsic in multiple-camera working with purely optical cameras is entirely avoided.

The film industry has already shown its awareness of the contribution which the electronic camera can make to smooth-running studio production by the introduction of an electronic aid in the form of a view-finder used in conjunction with multiple optical cameras. The advantages possessed by the combination of optical camera and electronic view-finder may be roughly summarized as follows. First, the element of operational blindness is removed; the director can study a camera-view of the shot during both rehearsal and the actual shooting. He can satisfy himself that the *découpage*, i.e. the breakdown into shots and angles, is as effective visually as it appears to be on paper. He can, whilst there is still time to alter or modify his own intentions, watch continuous sequences, and he is no longer compelled to work in a series of discontinuous glimpses. Finally, the electronic image can be multiplied and distributed, so that other key workers — the producer, the lighting engineer, the make-up supervisor, etc. — can exercise their own separate supervisions.

Because of these advantages the addition of the electronic view-finder to an orthodox camera is regarded as a progressive step; nevertheless, it is essentially a traditionalist solution to a problem which is amenable to more satisfactory solution by newer methods. If the electronic image produced by the view-finder on the camera (or rather the master image produced by the several view-finders on the various cameras in the unit) already exists in convenient form, the most rewarding course would be to improve the quality of that image until it attains technical parity with normal film, and then to photograph the master image itself rather than turn back to the individual cameras for the actual process of recording.

The advantages inherent in this method will already be apparent to any director who is familiar with modern television-studio technique. Once the electronic camera has been substituted for the optical camera within the studio the electronic image on the director's master-screen becomes not merely an accurate and helpful camera-eye view of the scene, but an identical reproduction, faithful in all respects with regard to lighting, focus, tonal gradation, brilliance, etc., of the picture which is to be, or is being, recorded. Moreover, the photography has taken place at the point where the contribution of the electronic unit and of the director's supervising intelligence are at their optimum. Not only can the "cuts," "fades," and "wipes" be recorded precisely as the director wishes, but this facility extends automatically also to mixes and superimpositions. Thus, at the end of shooting it is a portion of the fully finished film, rather than a collection of shots needing processing and editing, which the director of an electronic camera-unit has in his possession.

It is not the purpose of the paper to consider the advantages, in terms both of financial economy and of improvement in acting standards, which sequence shooting provides in comparison with the separate-shot method. The main issue is the question of the technical quality of recordings made from an electronic image. It remains, therefore, to show the reasoning which leads to the belief that recordings made by this method can produce film of fully acceptable technical quality.

(3) Overall Technical Considerations

It is clear that, to be acceptable, motion pictures made by the process described in the paper must to all practical intents and purposes be indistinguishable from those made by ordinary optical methods. This being so, an assessment of the average technical quality of pictures intended for theatrical release must be made, in order to determine the standard of technical performance which has to be achieved to attain the requisite effect. This is a difficult process, complicated by the profound influence of the artistic and entertainment value of the product, but whilst recognizing the overwhelming importance of these qualities in their proper sphere, the engineer must endeavour to disregard them and evaluate such purely technical quantities as he can. Even when he can assign objective values to the more measurable qualities, his task is still formidable, because the final result will be judged subjectively and no two people will agree what constitutes the most acceptable product when it comes to the portrayal of some particular scene. The most important qualities which must be assessed are, in order of relative importance, tonal range and fidelity of tonal reproduction, and picture definition.

(*3.1*) *Contrast Range:* Dealing first with tonal fidelity and excluding specialized shots where unusually small or distorted contrast ranges are used for special effects, it is generally conceded that the average motion-picture-film print has a useful detail-bearing contrast range of 0.2–1.5, expressed in terms of density = log $1/x$, where x is the transmission coefficient.

Extreme highlights, such as reflections from chromium-plated parts of motor cars, musical instruments, sequins and to a lesser extent glints in eyes, shine on hair, etc., are permitted to extend to a value of about 0.1, which is the density of the celluloid base and constitutes a burnt-out highlight which contains no detail, but the presence of which is essential to give sparkle to the picture. At the other end of the scale, there is usually no great advantage in reproducing dark areas of density greater than 1.5 with any detail, because the ambient light falling on the screen is sufficient to flatten them out, owing to requirements of safety lighting in theatres. Nevertheless, it is customary to permit extremely dark areas

to reach a density substantially below 1.5 without, however, containing much detail.

It may thus be said that the detail-bearing contrast range in an average motion-picture film, expressed in linear terms, is antilog (1.5–0.2) = 20:1. Allowing for extension to burnt-out highlights at one end of the scale (density = 0.1) and extreme blacks at the other (density = 1.7), the total contrast range is probably some 40:1 in the print itself.

It does not follow that this range of contrast will always be realized on the screen when the film is projected, because the actual limits of reproduction will vary enormously with many factors. The quality of the illuminant and optical system of the projector, the amount of ambient light reflected on to the screen by different decorative schemes in the auditorium and many other things all contribute to reduce the effective contrast of the picture.

These considerations aside, however, it seems clear that, to be comparable with normal motion-picture film, the release prints of motion pictures made by the proposed electronic process must have a total maximum contrast-range of some 40 or 50:1.

For the contrast characteristic required, normal practice in motion pictures is to work to an overall gamma of about 1.3, which corresponds to a mean gamma of about unity. It is clearly desirable that films made by the electronic method should conform to this convention and there is no difficulty in achieving this result. In fact, the electronic process offers the possibility of improvement, because the extreme flexibility of the electronic chain through which the signals corresponding to picture are passed allows almost any shape of transfer characteristic to be contrived, within broad limits determined by the signal/noise ratio.

This is very significant, because it means that inherent defects in photographs, which are cumulative throughout the printing and processing and which result in a far from ideal characteristic in the final product, can be corrected by electronic compensation when the electronic camera is used, whereas they have to be tolerated when only the ordinary optical camera is available. As a result, the film produced by electronic means should ultimately be superior in tonal quality to that made by normal optical methods.

(*3.2*) *Definition:* The study of definition in a photographic image is a difficult subject, and too much adherence to conventional approaches can lead to erroneous conclusion. A somewhat novel approach to the problem has therefore been evolved, in the hope that methods of measurement may emerge which are capable of yielding more realistic results than some of the methods used in the past.

For example, the resolving power of a lens or a film stock, or a combination of the two, is usually defined as a limiting resolution of so many lines per millimeter. This means that an image composed of a pattern of that line density is just discernible, i.e. it is an extinction value. Any detail finer than this is lost, falling within the circle of confusion of the lens or the film grain size, or some combination of the two.

This definition by itself is misleading in assessing the effective sharpness of the resultant picture. The limiting resolution figure is analogous to the ultimate cut-off frequency of a low-pass filter, or, with certain minor reservations, of any piece of television equipment, such as a video-frequency amplifier or television broadcast transmitter. It gives no indication of the performance of the equipment at frequencies in the pass region below cut-off.

Obviously, many factors, such as lens aberrations, flare, internal reflections and diffusion of light and grain structure in the photographic emulsion, etc., must contribute to this fall-off in response as

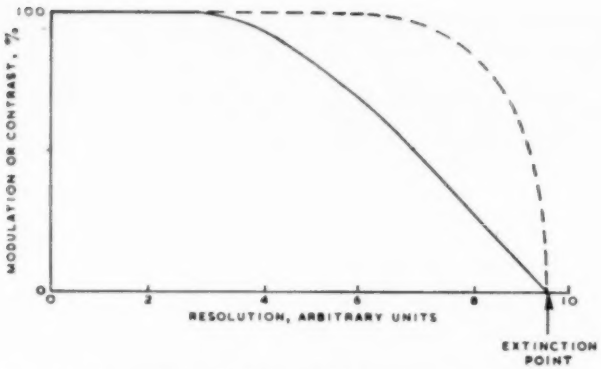

Fig. 1. Comparison of photographic contrast with television depth of modulation over total range of resolution.

——— Photography; resolution in terms of lines/mm.
- - - Television; resolution in terms of detail frequency.

the detail fineness approaches the limiting resolution or extinction value, but a mere statement of the resolving power does not disclose the rate at which the fall-off takes place.

In an attempt to reconcile the television and optical points of view, the authors propose to use a term which has come to be used, namely "detail frequency," which is the product of the number of lines per millimeter into which the object is dissected and the scanning speed. Detail frequency in television is thus the electrical counterpart of detail fineness in photography and its use permits comparisons to be made. It must be recalled, however, that 1 line/mm in photographic practice conventionally represents one white and one black line, whereas in television the black and white lines are counted separately, i.e. one photographic line equals two television lines. It must be added, moreover, that the detail frequency is to be regarded as the fundamental frequency generated by scanning a repetitive pattern. No account is taken of harmonic development at this stage.

Figure 1 shows an arbitrary comparison between the detail-frequency response of a television system and the detail response of a lens and photographic emulsion in comparable terms. To illustrate the point, the lens and film combination have been shown as having something approaching a normal aperture/distortion curve, whereas the television-system response has been maintained at 100% almost up to a sharp cut-off. The limiting resolution is the same in both cases.

It is believed that of the two reproducing systems, television will present a picture giving a greater subjective impression of sharpness and boldness of detail than the other, even though the detail cut-off frequencies are the same in both cases. The theory is advanced that subjective impression of definition can in some way be related to the ratio of the respective areas below the curves. The determination of this effect is complicated — like all comparisons of definition between television and photography — by the fact that television pictures are discontinuous in the vertical plane, whereas photographs are continuous in both planes. However, this does not necessarily invalidate the truth of the conception.

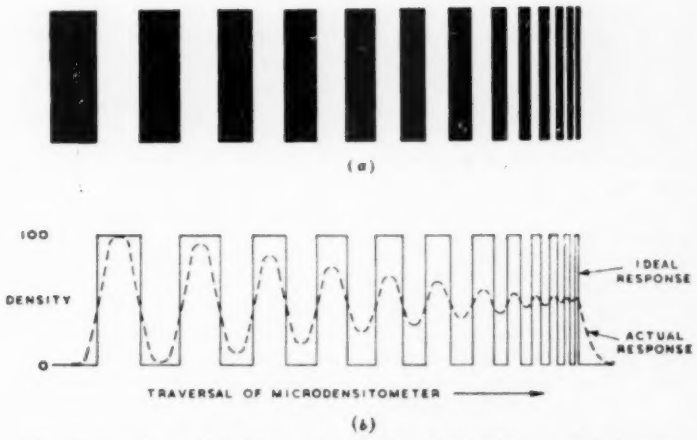

Fig. 2. Detail resolution test: (a) test card; (b) photographic image.

Another way of considering the same effect is to study the rate of change from black to white (and vice versa) attainable in photography. It is known that the transition from black to white in a photographic image is not infinitely rapid. In other words, the density change at the edge of an exposed area is gradual and not abrupt. Discounting contributions due to lack of sharpness in the lens, the main cause of the effect is hallation or dispersion in the grain of the emulsion. To demonstrate this effect, an image of alternate black and white bars of progressively smaller dimensions is explored by means of a microdensitometer, which is capable of measuring the density of areas small by comparison with the width of the narrowest bar.

The results of such an exploration are shown (greatly exaggerated) in Fig. 2. The full curve illustrates the ideal response, and the dotted curve the general shape of results attained in practice. It becomes apparent that the effect is precisely analogous with the distortion of a square wave which has been passed through an amplifier with an insufficiently short rise-time.

Investigation shows that the "rise-time" of different photographic emulsions varies greatly, for example, with grain size, etc., and it is not necessarily those emulsions that are capable of the greatest absolute resolution that possess the shortest rise-time for a black-and-white pattern of given fineness. It is believed that the picture which gives the best subjective impression of sharpness is the one that possesses maximum depth of modulation at higher frequencies and most rapid rise time, and that a figure of merit of apparent sharpness can be extracted, based on a mathematical combination of these two values. It will therefore be seen that to evaluate the quality of average motion-picture definition and to translate the result into terms of equal television definition is not a simple process. In consequence, it has been necessary to base the calculations on a simple conversion using such values as are generally accepted.

Before proceeding to numerical values it seems desirable to recognize that motion-picture technicians have, over a long period, arrived empirically at an order of definition which is adequate to satisfy the most discerning member of the public, even when sometimes projected through rather mediocre equipment. There is little doubt that twice or even

four times the definition could be realized, but it would be quite unnecessary and uneconomic to do so. The generally accepted standard seems to comprise a lens and negative-stock combination having a limiting resolution under best conditions of about 40 lines/mm on the axis, and some 30 lines/mm over the whole field of a frame (22.05mm × 16.03 mm).

After processing, the release print has a limiting resolution of about 25–30 lines/mm on the axis. This is not a very high standard of definition, and a single-35mm frame projected statically to normal screen dimensions generally appears fairly soft. Under running conditions, however, "dynamic resolution" makes its effect apparent and helps to produce an impression of adequate sharpness.

The mechanism of the dynamic-resolution effect lies in the fact that surface noise is random and adds from frame to frame in quadrature. The image, on the other hand, is repetitive and therefore tends to add arithmetically over a number of frames; moreover, the sharpness of edges is improved because a random succession of film grains, as it were, scan them and sharply delineate them.

For the choice of standards of electronic-image definition to give results comparable with motion-picture film produced by normal methods, it is necessary to consider the order of resolution required and that realizable in the present state of electronics. So far as image dissection is concerned, the only variable quantity is the number of lines, since the picture repetition frequency is fixed by motion-picture standards at 24 frames/sec. The decision regarding the number of lines controls many factors, of which the bandwidth of the system, the signal/noise ratio and the size of the scanning spot at both camera and reproducing tube are of cardinal importance. It is well known that, for a given number of lines, there is a calculable bandwidth which must be used in order to produce definition which is equal in both vertical and horizontal directions. It is worth remembering that the use of many more lines than the available bandwidth justifies can result only in progressive deterioration of the picture detail, since the detail frequency increases as the square of the number of lines.

The effect of increasing the number of lines, however, has a meretricious appeal, because of the finer resultant structure of the picture, but, whilst easier on the eye, it has no advantage for photography, where the linear structure is going to be eliminated in any case by one of the known expedients and out-and-out detail resolution is all that counts.

Considering, in the absence of anything better, a direct translation from optically produced film-definition standard to television, the following assembly of facts is arrived at:

The resolution of a normal motion-picture negative has been assessed, at best, to be about 40 lines/mm, which represents 80 television-picture points per millimeter.

Since the frame is 22.05mm wide, the definition along the line is equivalent to a total of 80 × 22.05 = 1,764 picture points.

This, however, is based on photographic limiting-resolution values, so that it seems possible, in the light of the foregoing arguments, that appreciably less television picture points would suffice to produce a picture of acceptable sharpness. In this connection, Kemp* has suggested that it would be permissible to introduce a factor C, of which he considers the value to be about 0.75, to compensate for the more rapid decay of response of the photographic system with increasing fineness of detail, as opposed to the maintenance of a high level of television modulation up to the frequency of cut-off. Application of this factor gives the definition along the lines as the equivalent of 1,764 × 0.75 = 1,323 picture

*W. D. Kemp, "Television recording," *J. Inst. Elec. Engrs.*, [London], *99, Part III A, No. 17:* 115–127, 1952.

points. Direct translation of this value into the number of lines from top to bottom of the picture gives $1,323 \times 0.75 = 992$ lines. The bandwidth required to transmit this detail, given by the familiar $L^2RP/2$ formula, is therefore $(992^2 \times 4 \times 24)/(3 \times 2) = 15.75$ mc.

It will be argued that it would not give a balanced picture, i.e. one in which vertical and horizontal definitions are equal, because of the line scanning factor K. Various values have been assigned to K, but taking it at 0.75, the number of lines is increased to $992/0.75 = 1,320$.

To sum up, therefore, definition along the line corresponding to one-thousandth of the picture height is required, but to take account of diversity in the discontinuous vertical direction, the number of scanning lines may have to be increased to 1,300 with a 25% increase in bandwidth to cater for the increased scanning speed.

However, because of the probably greater incidence of vertical than horizontal lines in a natural scene, it may not prove necessary to go much above 1,000 lines, and, since there is a tremendous advantage in keeping the writing speed as low as possible, this figure has been taken as a basis for first experiments.

It must be emphasized that the whole of the foregoing is advanced with extreme reserve and is, moreover, the subject of experiments currently being made, as much of it is based on pure supposition and on theories which have always been the subject of fierce controversy. Doubtless, calculations on other bases would yield widely divergent results, but the authors feel that it is essential to make some attempt to determine numerical values, as a starting point for practical investigation.

Quite apart from the foregoing, there remains the possibility of introducing novel means of picture dissection — which may prove more adaptable than scanning of the orthodox variety — to the production of motion-picture film by television methods. It is too early, however, to make more than a passing reference to such possibilities, and for the purpose of the paper the authors have confined their consideration to scanning of the conventional type.

(4) Interlaced and Sequential Scanning

For the purpose in hand the choice between interlaced and sequential scanning involves several important considerations. Interlaced scanning is universally used for broadcast television and, in this connection, is an extremely useful expedient. By interlacing, the apparent flicker frequency of the reproduced picture is doubled, without, however, any increase in the bandwidth required to transmit it. The principle of interlacing therefore possesses outstanding advantages for broadcasting in that its use transforms a television picture of comparatively low repetition frequency, which would exhibit considerable flicker if sequentially scanned, into one which within acceptable limits of brightness is effectively flicker free.

On the other hand, the introduction of interlacing is generally held to reduce the apparent definition of the picture as viewed by the eye. A number of effects are involved, of which three may be cited. First, slight inaccuracies of registration of the interlace raster result in "pairing" of the scanning lines, or, in extreme cases, superimposition of the lace and interlace lines. This is bound to reduce the definition progressively as the pairing effect becomes worse, until complete superimposition occurs, when the definition is theoretically halved. It is only fair to record that advances in design of scanning circuits have greatly reduced this defect in the last year or so.

Secondly, the movement of the viewer's eye when following vertically moving objects strobes the line structure and momentarily breaks the picture as seen into half the number of lines, giving the impression of a coarse line-structure. A similar effect occurs in

the television camera, where strobing can take place between the line scanning and objects moving up or down the vertical axis of the picture. Tilting of the camera can produce the same effect. It must be noted that in the recording of a television picture strobing effects are confined to the electronic pick-up camera and do not occur at the photographing point, because the photographic camera has a fixed viewpoint. Nevertheless, even in its reduced form, the result of "line crawl" introduced by the camera can be quite serious.

Thirdly, the use of interlacing gives rise to a particularly objectionable form of movement blur, because two discrete and separate images of a fast-moving object appear on the screen, displaced from one another by the distance through which the object has moved in the $\frac{1}{48}$-sec interval between the writing of the two superimposed rasters. This is a form of movement blur which finds no counterpart in the natural response of the eye or in normal cinematography.

On the question of recording television images on film, however, it will be immediately apparent that the need for interlacing fundamentally does not exist, because the standard picture repetition rate is 24 frames/sec, elimination of flicker being effected at the film projector, where the light is obdurated twice, or preferably three times, during the projection of each picture frame.

Freedom to use sequential scanning leads to a consideration of its advantages, which may be stated as follows:

(a) It is appreciably easier to obtain accurate registration of the lines in a sequential than in an interlaced raster.

(b) Movement blur, due to the formation of double images, and line crawl are eliminated.

(c) The obligation to produce an exact number of lines per frame no longer exists, which opens up possibilities of the introduction of advantageous effects analogous to the dynamic-definition effect.

(d) The number of frame-suppression periods per picture is reduced from two to one, thus materially increasing the "time efficiency" of the system.

It is thus suggested that sequential scanning presents so many advantages that its use is to be preferred. The serious disadvantage lies in the fact that the pictures viewed by eye, during production, suffer from the severe disadvantage of 24-cycle/sec flicker. There seems some hope, however, that the effect of flicker may be to a large extent reduced by the use of reproducing cathode-ray-tube screens having long decay times.

(5) The Electronic Camera

(*5.1*) *Brief Description of System:* To summarize the foregoing, it would appear that the use of a 1,000- to 1,300-line sequentially-scanned electronic image with a bandwidth of 15 to 20 mc will suffice to give adequate definition for the production of acceptable motion-picture film, provided that the whole system is sufficiently free from loss and distortion. The contention is advanced that definition of this order is within range of modern electronic equipment and that, within a short time, equipment which has been developed in the laboratory will be available in a form which will be suitable for use on the studio floor.

(*5.2*) *Optical Performance:* No limitation in definition is imposed on the system by the taking lens of the electronic camera, since good-quality 35mm lenses of to-day are capable at full aperture of resolving from 8 to 10 times the fineness of detail normally required for making a film optically. The use of a standard range of 35mm lenses also ensures that depth of focus, taking angles and so on, are exactly similar to those to which film technicians are accustomed.

(*5.3*) *Handling Characteristics:* Electronic cameras can be made in conventional shape, but much smaller and

lighter than their optical counterparts. No form of "blimp" is necessary, because the electronic camera is completely silent. No necessity for reloading exists, and the cameras will operate for long periods without attention.

Apart from this, the camera handles in exactly the same way as any film camera, and the camera operator, if he so wishes, may adopt entirely conventional methods of view-finding, focus-pulling, etc. On the other hand, he has open to him entirely new features, such as cathode-ray view-finder, remote turret and iris operation, as well as facilities for remote or even automatic focusing, including splitting focus.

Only time can show how he will choose to employ these facilities, but it seems very probable that a technique can be built up using some or all of them with a material increase in efficiency of working.

(*5.4*) *Technical Performance Requirements:* The electronic camera must be capable of resolving some 1,000–1,300 lines and generating a substantial amplitude of signal up to the highest detail frequency.

The photometric response must be such that a substantially linear characteristic can be obtained, with correction, if necessary, for a 50:1 range of light intensity.

The signal/noise ratio of the whole system must be not worse than −30 db on peak white.

The camera must be free from shading and vignetting effects and spurious signals generally, and it must maintain constant illumination over the field and a constant black level under the exacting conditions of practice.

The sensitivity of the whole system must be at least equal to or greater than that of a normal film camera used with fast negative stock, and the scanning geometry must be of a very high order of accuracy, say within 1% in terms of velocity.

The associated equipment must have sufficient gain for the purpose in hand and a handling capacity large enough to allow for pre-emphasis at the higher frequencies, if necessary. It must be free from phase distortion or overshoot generally.

Facilities must be provided for gain adjustment, shaping of amplitude characteristic and the introduction of pre-emphasis.

Finally, means must be provided for cutting, fading, mixing or superimposing the pictures from a number of cameras and introducing electronic wipes, overlays, matte and other process shots, as well as programme material derived by telecine scanning of film taken elsewhere of exteriors, etc.

(6) Recording Cathode-Ray-Tube Unit

As in the camera, the scanning geometry of the recording unit must be of unimpeachable accuracy and the spot size sufficiently small to resolve the requisite definition without appreciable loss.

The tonal response must be either linear or capable of being shaped to compensate for the film-gradation characteristics. The maximum available peak brightness must be sufficient to reproduce the highest burnt-out highlight without "white flattening" or defocusing.

Steps must be taken to reduce dispersions or reflections of light so as to preserve the maximum contrast range, and the recording tube must be set up *vis-à-vis* the motion-picture recording camera in such a way as to minimize the effects of vibration.

(*6.1*) *The Mechanism of Photographic Recording:* The choice of a means of photographing the image on film in the form of a motion picture poses a number of serious questions. Numerous methods have been proposed to bring about the desired result, but, broadly speaking, practicable methods tend to fall into one of two main categories, namely inter-

mittent or continuous motion. The relative merits of the two systems, in their various applications to television recording are discussed by Kemp (*loc. cit.*), and there is therefore no need to enlarge upon them here.

It must be noted, however, that Kemp's approach to the problem is conditioned by the fact that his treatment concerns the problems of recording broadcast television, where the worker is presented with a composite signal intended for reception on a normal television receiver. The form of this signal is fixed and he cannot in any way vary it.

The authors, on the other hand, are at liberty to make any changes in signal waveform that they see fit and consequently their conclusions are influenced by the greater degree of freedom open to them, as well as by the fact that they are working to much higher standards of definition, which in turn bring special problems.

Whilst there can be no doubt that continuous motion is exceedingly attractive from many points of view and may prove to be the ultimate solution, the accuracy of registration which can be realized in the present state of development is insufficient for recording pictures of the order of definition required. In consequence, attention has been directed to the intermittent system, which has been proved by many years' use in the motion-picture industry to give a very high degree of accuracy of registration.

The application of the intermittent movement to the problem of recording high-definition electronic images has, of course, been greatly eased by the freedom to adapt the signal waveform to suit the operating conditions of the photographic camera.

To illustrate the degree of this easement, consider the case of recording broadcast television with an intermittent camera. If the maximum picture information is to be recorded, the film shift must take place completely within every other frame-suppression interval. This means that the film must be accelerated, decelerated, brought to rest and registered in a period of 14 television lines, which represents a time interval of about 1.4 millisec, or 12° rotation of the film-camera mechanism.

Expert opinion indicates that a film shift of this speed is on the limits of possibility, and that even if improved design enabled it to be realized, the strain on both film perforations and mechanism would be such as to make frequent jams and stoppages unavoidable and to render maintenance extremely difficult and costly.

No such mandatory condition exists in the requirements of the proposed system of high-definition recording, and it is possible to choose a frame-suppression interval of any length desired. Any increase would, of course, be made at the expense of the time efficiency of the system, i.e. the ratio of the time during which information is passing to the time during which the system is inoperative during suppression. Nevertheless, a useful compromise may be struck in which the gains accruing from the use of a longer frame-suppression period outweigh the loss in terms of time efficiency.

As stated earlier, the use of sequential scanning gives a substantial gain over interlaced scanning, since there is only one frame-suppression period per frame in the former as against two in the latter. The authors, therefore, advocate an intermittent camera with an accelerated film-shift operating during the frame-suppression period.

(*6.2*) *Exposure Time and Movement Blur:* Some consideration must be given to exposure time in an electronic, as opposed to a photographic, camera. In normal motion-picture work, the maximum available exposure is usually 180°, and although practice varies, the usual run of pictures is shot at full exposure. Shorter exposures, obtained by reducing the shutter-opening angle, are generally used only for scientific investigations.

The effect of using a comparatively long exposure of, say, $\frac{1}{48}$-sec in a photographic motion-picture camera is to produce a measure of movement blur, which is usually regarded as beneficial in smoothing out movement and preventing the formation of discrete separate images of a fast-moving object in successive frames. Picture-goers are used to this effect, and it enhances the impression of movement as portrayed on the screen.

In the high-definition electronic camera, the actual time the scanning beam is traversing each picture point is about $\frac{1}{48}$ microsec, or a million-times shorter exposure, since this would be the effective exposure if the camera had no memory effect. Fortunately all electronic cameras have some "memory," and it is possible to proportion the memory to give an adequate impression of movement.

In the early days of television broadcasting some cameras had a very short memory, and a fast-travelling ball, for instance, appeared as a line of white dots. An exceptionally long memory, on the other hand, is equally disadvantageous, because under these conditions very serious blurring will occur on moving objects and when the camera is panned.

A compromise is therefore necessary, and motion-picture experience indicates that a storage memory of 0.25–0.5 frame in length is likely to be satisfactory. It is not thought that the effect is particularly critical, and most television cameras in use to-day do not show any unpleasant effects in this connection under any reasonable conditions of working.

(7) Choice of Film Stock

A considerable degree of latitude exists in the choice of film stock for the recording camera, by virtue of the fact that the amount of light emitted by the recording cathode-ray tube is independent of studio illumination and may be kept constant under all conditions. Processing to constant gamma as opposed to constant density is facilitated by this.

Moreover, much more light is available at the film than when it is exposed in an optical camera, not only because the intensity of light emitted by the cathode-ray tube may be made several times that of the light reflected from a studio scene, but also because the optical system used with the photographic recording camera can be made more efficient than that which it is possible to use on a studio floor. Magnification is constant and negligible depth of focus is required, because the cathode-ray screen is a flat field.

In consequence, comparatively slow film stocks can be used, with advantage in terms of resolution, rise time, absence of granularity and linearity of tonal characteristic. Moreover, images on fine-grain negative are known to suffer proportionately less in processing and printing than those on more sensitive and coarser-grained emulsions.

(8) Conclusion

Whilst encouraged by the results of laboratory and studio tests to date, the authors are conscious that the paper is necessarily tentative in its conclusions and is in many respects lacking in precise data. However, in view of the rapidly developing interest in electronic film-making, they felt that an interim paper of this nature would nevertheless be of interest.

(9) Acknowledgments

The authors are indebted to: Pye, Ltd.; the J. Arthur Rank Organization; London Film Productions, Ltd.; Eastman Kodak, Ltd.; E. F. Moy, Ltd.; and W. Vinten, Ltd., for information and assistance.

The authors also wish to express their thanks to Mr. W. D. Kemp and Mr. B. R. Greenhead for their help in the preparation of the paper.

Discussion for This Reprinting

By Pierre Mertz

The paper by Messrs. Collins and Macnamara describes a proposal that will be followed with great interest, for the application of television to motion picture production techniques. The objective "that, to be acceptable, motion pictures made by the process described in the paper must to all practical intents and purposes be indistinguishable from those made by ordinary optical methods" will appear especially challenging.

A point which the authors undoubtedly have in mind, but do not emphasize, is that in large measure the television processing which they are proposing is to be inserted in tandem with the photographic and optical techniques at present existing. Thus to set detailed objectives on quality it is necessary to investigate not merely the performance of the latter processes, but also the additional impairment expected from the insertion of the television processing. In such a case, in general, the inserted impairments need to be not simply of the same order of magnitude as those already existing (in the optical and photographic processes) but one or two orders of magnitude lower.

The authors are diffident about the tentativeness and controversial nature of their data and conclusions on photographic and television performance. Because of this it would seem helpful in a number of places if they could give documentation for the data they introduce. In particular, the authors have not referred to the extensive work of Otto Schade[1] on many questions which apply closely to their problem Other specific points upon which documentation would be helpful are:

(a) The film density ranges mentioned by the authors seem modest compared to the projection density measurements reported by Tuttle[2] in 1936. Tuttle's minimum densities run a bit higher than the authors': at low, 0.18; median, 0.41; and high, 1.05. His maximum densities, however, run substantially higher: namely, low, 1.90; median, 2.21; and high, 2.65. The influence of stray light in the theater on the projection contrast was discussed in a symposium of the SMPTE in May 1951.[3] S. K. Guth, in particular,[4] mentions a maximum desirable level giving 0.07 ft-L on the screen (which has a clear screen brightness of 5 ft-L). This leads to an equivalent density of 1.85, which still is over the authors' allowance of 1.7.

(b) The authors' figures on motion picture definition correspond generally with those found by an SMPTE committee in 1946 and referred to by Schlafly[5] in 1951. It would be interesting, however, to have more specific information on the "good-quality 35mm lenses of today . . . capable at full aperture of resolving from 8 to 10 times the fineness of detail normally required for making a film optically."

(c) The explanation which the authors give of "dynamic resolution" is the conventional one. However, in any casual experience which I have had, the increase over the "static resolution" was not realized, possibly due to "jump" and "weave" of the picture. It would be interesting to have any documentation on actual experiments which the authors might know of.

(d) Again on the subject of definition,

At the request of the Chairman of the Society's Board of Editors, at the time of reviewing this paper, this discussion was prepared by Pierre Mertz, Bell Telephone Laboratories, Inc., 463 West St., New York 14, N.Y.

the Fig. 1 which the authors show represents the familiar sharp drop in television resolution towards the extinction point. However, it has been shown in the work by Schade that if the influence of terminal equipment is considered in addition to that of the electrical circuit, the shape of the characteristic obtained shows a gradual drop, not too different from the photographic characteristic. This is illustrated, for example, by Figs. 100 and 101 of the 1948 paper.[6]

(e) The authors attribute to Kemp a suggestion for the use of a factor C = 0.75 to compensate for the decay, towards the extinction point, of the resolution of the photographic as compared with the television system. I have read through the Kemp paper referred to, No. 1351, fairly carefully but cannot find the suggestion.

(f) The authors mention a proposed signal-to-noise ratio requirement, to avoid degrading the film picture, of 30 db. American estimates of the performance of film run appreciably higher.[7] Figures (excluding allowances for synchronizing pulse and excluding frequency weighting) have been presented of 42 to 47 db, and even higher. Possibly the authors are measuring the random noise peak-to-peak, instead of rms, but even this would not account for all the apparent discrepancy. It is noted that no figures at all are given on specifications for shading or phase distortion, although these are apt to be important impairments in present-day television.

(g) It would be interesting to know if the authors have any specific information in mind on the "probably greater incidence of vertical than horizontal lines in a natural scene."

It is a little odd to find, after an admirable discussion of the advantages to be gained by the presentation to the director of exactly the picture which will ultimately be obtained from the film, that the authors are so little bothered by the problem of flicker on the director's monitor. With the use of the sequential scanning and the frame frequencies mentioned, together with a useful picture brightness, one wonders if the flicker will not be sufficient to ruin the director's artistic judgment. It would be interesting to have more information on the speculations regarding the possibilities of long decay phosphors in avoiding this, without unduly blurring the outlines of objects in motion.

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and film industries," *Jour. SMPTE, 56:* 44–51, Jan. 1951.
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Author's Comments

The authors were careful to point out that this paper was of an essentially interim nature, and did little beyond defining some of the major difficulties with which those who seek to make motion pictures by a television intermediate process are faced.

This being the case, the authors deliberately refrained from making reference to the very considerable amount of bibliography which exists on this subject.

The introduction of any additional process into a reproduction system must degrade the result *unless* the additional process can be made to correct errors in the process. It is certainly possible to apply electrical corrections for tone distortions introduced by the film characteristics, and by overemphasis of the higher detail frequencies it would appear also possible to correct in a large degree for aperture distortion, lens losses, etc. (As an analogy it is interesting to recall that the introduction of an electrical process into the recording of sound on disc — essentially a mechanical process — considerably improved the overall results.)

The authors, moreover, believe that other gains in terms of definition can be achieved. For example, it appears that the present average standard of quality in motion pictures has gradually advanced, against economic pressure, to a state where it is generally acceptable to the picture-going public. There seems good reason to suppose that if higher processing costs could be justified, marked improvements could be effected both in the production of the original negative and its subsequent reproduction through the stages leading up to the multiple release print.

The authors feel that if the economic advantages they claim for the process which they advocate are realized, some proportion of the savings will be available to improve the photographic part of the process with considerable gain in overall results.

Dealing now with the other points in the discussion, the authors would make the following comments:

(a) The film density ranges which they have mentioned were those quoted by a well-known manufacturer of film stock and the authors took them as a fair average basis on which to work. In point of fact there is no difficulty in extending the contrast range to any value which the film will accept so that the figures reported by Tuttle could be realized without serious difficulty.

(b) The authors admit that the statement that "good-quality 35mm lenses of today are capable at full aperture of resolving eight to ten times the fineness of detail normally required for making a film optically" is misleading if divorced from its original context, which was omitted from the paper at a late stage for security reasons. They can only repeat the view of a leading lens designer who states that "an $f/2$ lens can provide on Maximum Resolution Plates, 8 to 10 times the axial resolving power obtained with emulsions used in the film industry. Thus one could argue that it is the fact that the film industry uses grainy emulsions which defines fineness of detail."

The authors hold the view that this increased resolving power may to some extend be exploited.

(c) The authors believe that the conventional explanation of "dynamic resolution" is valid, and although it is difficult to establish quantitative results they have carried out a number of experiments which by observation were extremely convincing and in which the effect of dynamic resolution was most marked.

(d) The authors are only too well aware of the losses introduced by terminal equipment and as previously stated have been at pains to introduce into the electrical circuits corrections to compensate as far as possible for them. The limit to this process is, of course, the signal-to-noise ratio. To date they have been surprised

at the good signal-to-noise ratio they have been able to obtain.

By scrupulous attention to every element in the chain they have been able to preserve a good relationship between contrast in the object and in the image photographed on film up to the highest resolution powers of which the system is capable. They are confident that this result is capable of extension to higher definition by expedients which they hope to describe in due course. It should be mentioned in passing that particular attention has been given to the design of kinescope recording tube screens so as to maintain high contrast at the finest detail and eliminate as far as possible reflections and diffusion effects which militate against the desired result.

(e) The factor attributed to Kemp was omitted from the published version of his paper.

(f) The acceptable ratio between signal and noise seems to depend largely on the nature of the noise. The authors took a number of examples of optically produced film exhibiting normal grain structure and made a series of statistical tests against television picture recordings on fine-grain film in which the noise was of a fairly high-frequency type.

When the two results were adjudged to be as nearly comparable as could be determined by observation, the level of peak noise in the television picture was found to be some 30 db below peak white.

Had there been a preponderancy of low-frequency noise in the television picture it is highly probable that some ratio of the 40–50 db order would have been required, because not only is the high-frequency noise attenuated in the photographic process, but it is less apparent to the eye because of its finer structure.

As regards shading and phase distortion, the authors have worked to a condition of no visible shading in the photographic image, but with a progressive increase in brightness towards the edges of the picture amounting to some 15% at the extremes to compensate for lens vignetting. It has been found advantageous in some cases to overcorrect the final product to compensate for the projector objective. Phase compensation throughout the system is advocated so that no visible overshoot occurs at any frequency within the limits of the response of the system.

(g) The authors regret that they cannot quote any scientific evidence regarding the greater incidence of vertical as opposed to horizontal edges in a natural scene, but they have frequently heard the view expressed that the former tend to preponderate.

In conclusion, the question of flicker on the director's viewing screen has proved curiously unimportant. At a brightness consistent with fairly low levels of ambient illumination the flicker is singularly inobvious and after a few minutes the observer gets used to it and forgets it entirely. The wearing of dark glasses has been recommended and certainly assists in this connection, but never at any time during the authors' work has any serious complaint of flicker been voiced. Reproducing tubes having a moderate decay are used at present and the development of tubes having some approximation to a square decay has made some advance. Unfortunately, however, no information can be disclosed on such tubes at the present time for security reasons.

Signal Corps Mobile Television System

By JOHN S. AULD

The U.S. Army Signal Corps' mobile television system is briefly described. In this system five vehicles — a transmitter bus, transmitter power bus, receiver bus, receiver power bus, and kinescope recording bus — are used to provide a complete television unit designed to meet training and operational requirements of the Army.

In 1948, when television began to pass from its embryonic stage, the Army decided that it might be employed to answer some of its tactical and training problems. Television had been used during the latter phase of World War II on an experimental basis, using highly specialized nonstandard equipment, with excellent results.

The question arose as to what units would receive television equipment, what type, and how would it be employed? It was decided that the most practical and economical method of answering these questions was to design one complete and self-contained system on wheels. This unit could then travel from post to post stimulating thought, and showing field commanders of the various branches of service (i.e. artillery infantry, etc.) how television might solve some of their particular problems. The information obtained from these demonstrations would then form the basis for specifications of specialized equipment to meet these individual needs. This was the inception of the Signal Corps Mobile Television System.

Presented on October 7, 1952 at the Society's Convention at Washington, D.C., by Sgt. John S. Auld, Technical Director, U.S. Army Signal Corps Mobile Television System, Signal Corps Photographic Center, 35–11 35 Ave., Long Island City 1, N.Y.

The Transmitter Bus

The basic layout of this vehicle is quite similar to that of the average commercial remote pickup bus but, because it has to provide all the station programming facilities, it is much more elaborately equipped.

This unit houses three, RCA Type TK-30A, field camera chains. The camera controls and power supplies are placed console fashion across the rear of the bus. Behind this operating position there are five cable reels. Four of these carry 250 ft of camera cable each; the fifth, 1700 ft of microphone cable of various convenient lengths.

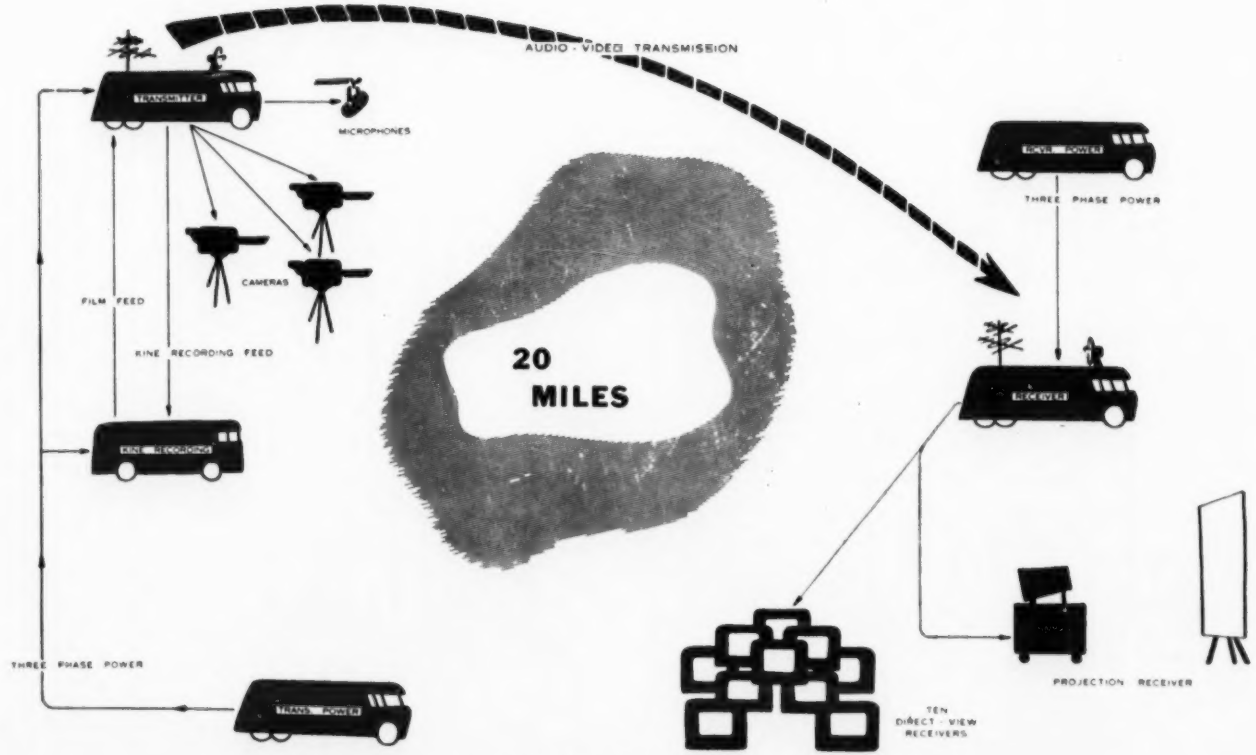

Fig. 1. Flow chart of the Signal Corps Mobile Television System.

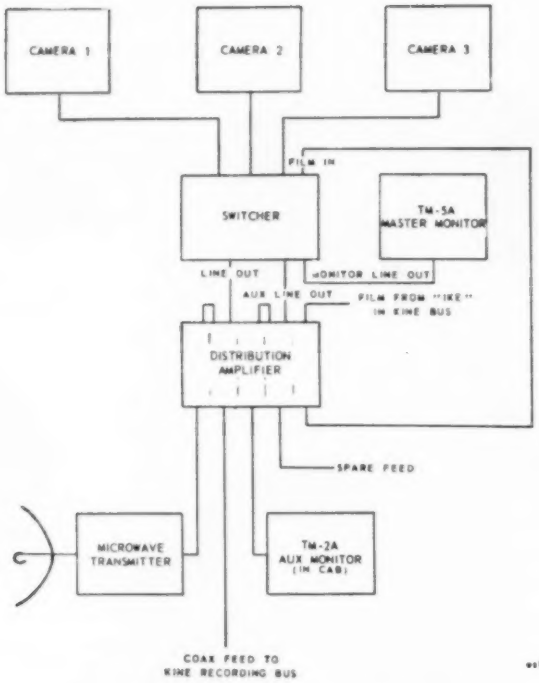

Fig. 2. Transmitter bus — video distribution.

It may be stated here that all the reels in the vans are power-driven on take-up by an ordinary portable electric drill with a $\frac{1}{2}$-in. chuck. Needless to say that since the system carries 18,000 ft of assorted cable this is quite a time and labor saver.

Originally the film chain was placed in the receiver bus due to a lack of space in the transmitter bus. This handicapped the program director in that he could not preview film. When a kine-recording unit was added it was decided to remove the film chain from the receiver bus and place it in the kine-recording van since this van was to be located next to the transmitter bus and the two attached directly by cable.

Film video signal now feeds through coaxial cable to an isolation amplifier in the transmitter bus and from there to an auxiliary input of the switcher where it can be previewed on the master monitor by throwing a monitor selector switch.

As can be seen in the block diagram of Fig. 2, the line output of the switcher feeds both the microwave unit (a standard RCA Type TTR-1B on 7125 mc) and the kine-recording bus through a paralleled distribution amplifier. The auxiliary output is also paralleled to feed the TM-2A auxiliary monitor in the cab, an announce position, and also a feed for stage monitor.

Two RCA Type OP7 portable mixers feeding a single OP6 amplifier provide eight low-level audio inputs. For ac-

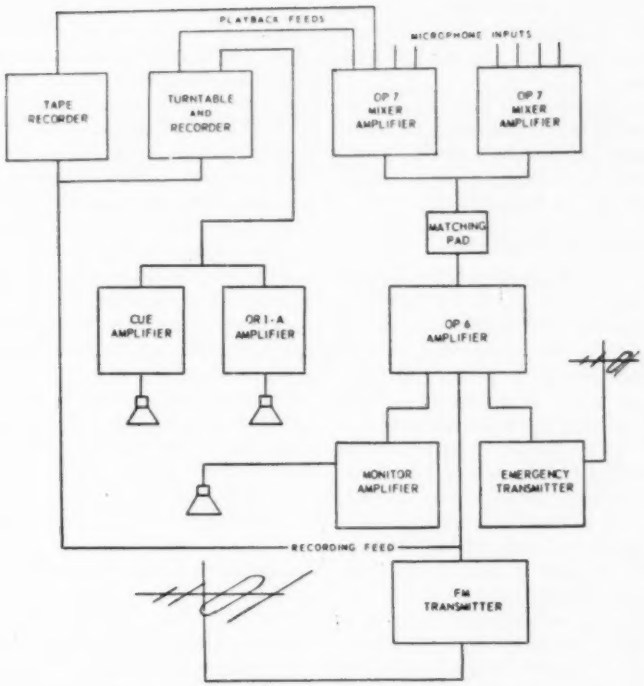

Fig. 3. Transmitter bus — audio distribution.

cessibility and ease of operation all microphone inputs, P.A. speaker feeds and intercommunication jacks are mounted on an aluminum strip which runs the width of the bus just below the cable reels. An RCA RT-11A rack-mounted (studio-type) tape recorder, a portable disc recorder-turntable, and a 30-w Brook amplifier with a bass reflex speaker used as a monitor system assure adequate audio facilities.

Figure 3 shows a simple block diagram of the audio layout. The OR-1A amplifier and its associated speaker serve as a public address or talk-back system when necessary.

The audio signal is transmitted to the receiver bus by a 45-w, phase-modulated, police transmitter which has been modified for high fidelity. A four-element yagi* is used as an antenna. A bridge off the program line feeding the transmitter feeds audio signal to the kine-recording van.

Each of the four vans is equipped with an FM transceiver on 163 mc which serves as an engineering line. Provision is made to operate these units from the bus battery as well as a-c so that communication can be maintained while the vehicles are in motion. An additional transceiver, on 173 mc, is provided in both the transmitter and

* Antenna array devised by Hidetsu Yagi in 1928. It consists of an active dipole and several short-circuited dipoles serving as directors and reflectors, to give a narrow beam.

receiver bus as a production line and also as an emergency audio transmitter in case of failure of the main 45-w equipment.

The transmitter bus can operate on either a three-phase, four-wire, 220/110-v or a single-phase 110-v system. Three variacs used in conjunction with a voltmeter provide for balancing the load.

The Transmitter Power Bus

A serious difficulty in most remote pickup setups is power availability. The purpose of this vehicle is to remove this problem. It houses two 15-kva motor generators in a compartment just aft of the cab. A single 55-gal gas tank serves both the bus and generator motors. This allows the generators to run under full load for ten hours without refueling which is more than enough time for the average demonstration.

The generators supply three-phase 208/110-v power to two Russell and Stoll output plugs located on the side of the bus. By connecting the output of each generator to the arm of a 3-pole, double-throw switch either generator can feed either plug or in emergency any one generator both plugs. The governor on the motor holds the output frequency within a half-cycle once it has been adjusted for a constant load. By operating the synchronizing generators with a long time-constant in the AFC circuit they lock in very well on 60 cycles.

Two 250-ft reels of four-wire #6 power cable are utilized to keep the line losses low while separating the vehicles to minimize the generator noise in the audio pickup. Two other reels carry additional camera cable, RG-11U coaxial cable for video feeds, and two-wire #10 cable for lighting and power extensions. The reels are accessible from the outside by the use of small ports in the side of the bus.

The rear compartment of this vehicle contains two work benches for equipment maintenance. Below the benches and the reels are cabinets and drawers for spare parts and tools. The drawers have removable dividers for greater utilization of space.

The Receiver Bus

As its name implies this vehicle provides the receiving facilities for the system. This consists of ten 16-in. receivers and one large-screen projection receiver which have been modified so that they are capable of being either "line" or "air" fed. As was mentioned previously, this unit may be located up to 20 miles from the point of program origin.

Most of the equipment used in reception is contained in two 6-ft racks mounted in the rear of the bus. Two doors make the back of the rack easily accessible from the outside.

Video signal from the microwave receiver is passed through a stabilizing amplifier to clean up the synchronizing pulses and to make sure of the synchronizing pulse-to-video signal percentage. This stabilizing amplifier has two outputs, one of which feeds a 12-in. monitor mounted alongside the rack and the other feeds two unity-gain distribution amplifiers having ten isolated outputs. The input and output of all equipment comes up on coaxial patch panels with parallel jacks for versatility and quick checking with an oscilloscope. In the present setup the output from one of the distribution amplifiers feeds a "Dumitter." The Dumitter is a closed circuit (nonradiating) transmitter whose function is to take audio and composite video signals and modulate a carrier on television channel 3. This modulated RF signal can then be sent over coaxial line to as many as 125 commercial receivers of 72-ohm input using a line distribution arrangement without modifying the receiver to a line-driven monitor. Small distribution boxes are provided with the Dumitter having one input and five outputs. By utilizing these boxes all ten receivers may be

placed up to 1500 ft from the bus by the outlay of only 3000 ft of RG11/U coaxial cable, and ten small lengths of RG59/U to couple the boxes to the receivers. To accomplish this same feat using the standard distribution amplifiers carried in the receiver bus would mean running 15,000 ft of special cable (single coaxial and an audio pair). Eleven 500-ft lengths of this special cable were supplied with the system but along with the distribution amplifiers are now relegated to emergency and special service.

Program audio signal is received on a single-channel FM receiver with double conversion. A four element yagi is used as an antenna. The receiver output feeds the Dumitter, a monitor amplifier, and a multi-winding transformer with one input and eleven outputs. This transformer provides a direct "line" feed to the receivers when desirable.

Three auto-transformers boosting the line voltage 5 v feed eleven a-c outlets located in the rear of the bus. These outlets are used in conjunction with 5,500 ft of two-wire #12 cable, carried in the receiver power bus, to provide power to the receivers. The auto-transformers make up for the losses ipcurred by long power runs.

The Receiver Power Bus

The layout of this vehicle is quite similar to that of the transmitter power bus. The main difference is that it has one 15-kva motor generator which allows for a larger rear compartment. This compartment contains ten reels which hold 500 ft of microwave cable, 250 ft of four-wire #6 power cable, 5,500 ft of special receiver cable, 5,500 ft of two-wire #12 receiver power cable, 2,000 ft of RG11/U coaxial cable, and 1,500 ft of RG59/U coaxial cable. This compartment also houses two workbenches. One of these is set up as a receiver test bench complete with television sweep generator, sweep calibrator, vacuum tube voltmeter and oscillograph. Cabinets and drawers, below the workbenches and reels, house spare tubes and parts.

The Kinescope Recording Bus

This unit is the latest addition to the system. The vehicle is a Fagoil-type "Twin Coach." It is a standard Army vehicle and is ordinarily used as a 36-passenger bus or for carrying litter patients. Upon receiving this unit we removed the seats, blanked out the windows and in general, made the operating section of the bus light-tight. A plywood partition with a sliding door separates the cab from the operating section.

Ordinarily, prints are made of the "kine-recordings" so negative recording is used and the sound recorded on a Westrex 16mm portable tape recorder. When only a single print is desired positive recording is used and the sound recorded right on the film by a Maurer sound head. At the time of writing no development and printing methods have been established since the installation has not been completed.

As mentioned previously, the iconoscope film chain is now located in this vehicle. The chain has been laid out in such a way that one man can handle the operation without leaving his operating chair.

The bus contains cabinets for film and spare parts storage. Two reels contain enough cable to locate this vehicle up to 150 ft from the transmitter bus. The reels are accessible from the outside of the vehicle.

Employment of the System

After a period of testing and break-in the unit embarked on its first mission 18 February 1952. This mission was to provide television facilities for the Army Field Force Commanders' Preventive Maintenance Course held at Aberdeen Proving Ground, Maryland. Upon arrival demonstrations were set up and a weekly schedule arranged. Four of

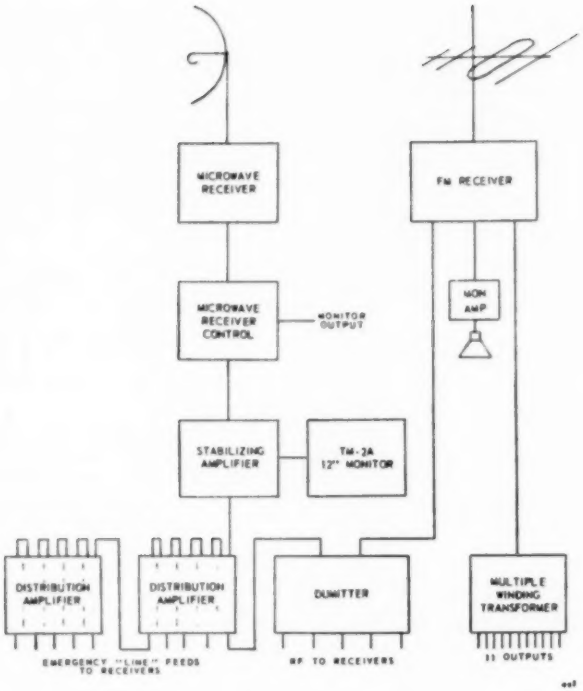

Fig. 4. Receiver bus — audio-video distribution.

these shows were studio presentations and covered preventive maintenance in the various branches of service. The other two were remotes of which more shall be said later.

For the studio presentations a theater was utilized. The transmitter bus was used as a control room. Ample commercial power was available so the motor generators were not needed. Camera cables, microphone cables, talkback and PL lines, and coaxial cable feeds for stage monitors were run into the rear of the building. The theater had only been used for motion pictures and therefore had very poor lighting facilities. Scoops and spots were obtained to supplement the portable lighting equipment carried by the system. Everything was installed on a semi-permanent basis so that if a remote pickup was contemplated the only thing necessary was to disconnect the cables from the van, load in the cameras and be off.

The receiver bus was parked close by with five video-audio lines to two classrooms. The large screen projection system was installed in the front of the classroom flanked on either side by a 16 in. receiver for students whose viewing angle to the large screen was too acute.

Each week the officer-students answered a questionnaire after seeing the foregoing productions. Results showed that the utilization of television as a training aid was highly successful.

The most important of the remote pickup programs was entitled "The Video War Room." This program

taxed the engineering facilities of the system to the utmost. The production portrayed tactical television as it might function in the future. Cameras were concealed in a barn loft observation post, and by utilizing some eighty enlisted men as friendly and aggressor troops, along with tanks and planted charges, it realistically demonstrated how television front line cameras could send information back to division level where it could be analyzed by the Division Commanding General and his staff and acted on accordingly.

While this production fulfilled the unit's primary mission of stimulating thinking about the tactical use of television, it also emphasized to the engineer the need for simple, compact portable equipment with a low power drain.

In May 1952 the unit participated in several exhibitions including the Armed Forces Day Exhibition at Bolling Field, Washington, D.C. The unit then departed for West Point, where it provided television facilities and was on exhibition for June Week.

Closed-Circuit Television Demonstration at NOL

The use of short-range closed-circuit television for scientific and plant operation demonstrations is attracting wide attention in many areas today.

The 72nd Semiannual Convention of the SMPTE held one meeting in the U.S. Naval Ordnance Laboratory. Since security restrictions and time would not have permitted the members to visit the large wind tunnel facilities, a telecast was arranged through the medium of a closed-circuit television system provided by the Army Signal Corps.

The audience of approximately 150 persons was addressed by Dr. H. H. Kurzweg, Chief of the Aeroballistics Research Division, in the NOL auditorium.* Then the program was switched to the wind tunnel building about one-half mile away. The picture and sound for the telecast from the wind tunnel were transmitted over an interconnecting relay link. The picture was viewed on theater projector system and several standard television receivers in the auditorium. Sound was heard through the auditorium sound-reinforcing system and was recorded through the plant sound-recording system.

A communication system was set up to interconnect the wind tunnel program director, link transmission truck, link receiver truck, auditorium moderator and the recording facility. Included in the system were extensions to dial phones, special telephone lines and radio transceivers where telephone lines were not feasible.

Through television, the audience saw and heard actual wind tunnel operations explained by the Chief of the Design and Operations Division, J. R. Lightfoot. Schematic diagrams were used to demonstrate the essential components of the large supersonic wind tunnels for research and development testing at equivalent air speeds up to five times the speed of sound and of the similar hypersonic tunnel at speeds up to ten times that of sound.

The working section of the large Tunnel 1 was kept open to show the nozzle contour and the missile model positioned on its support. Tunnel 2, also a 40 × 40 cm tunnel and identical

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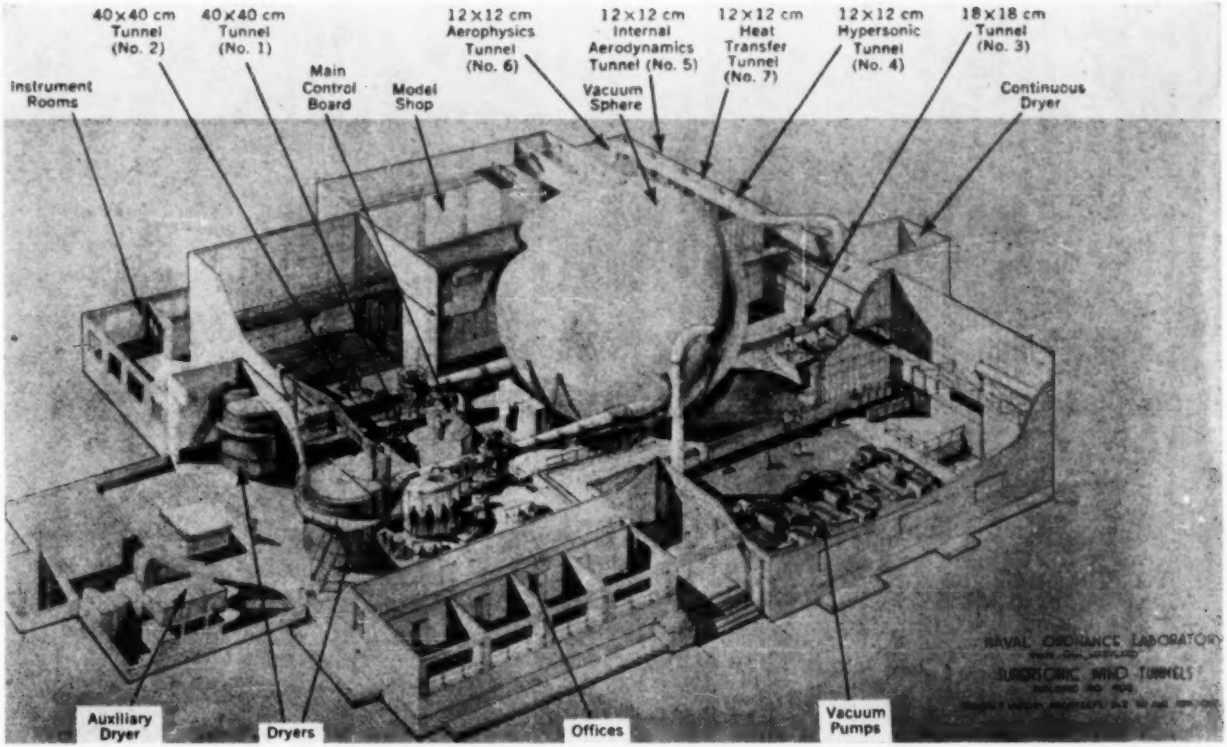
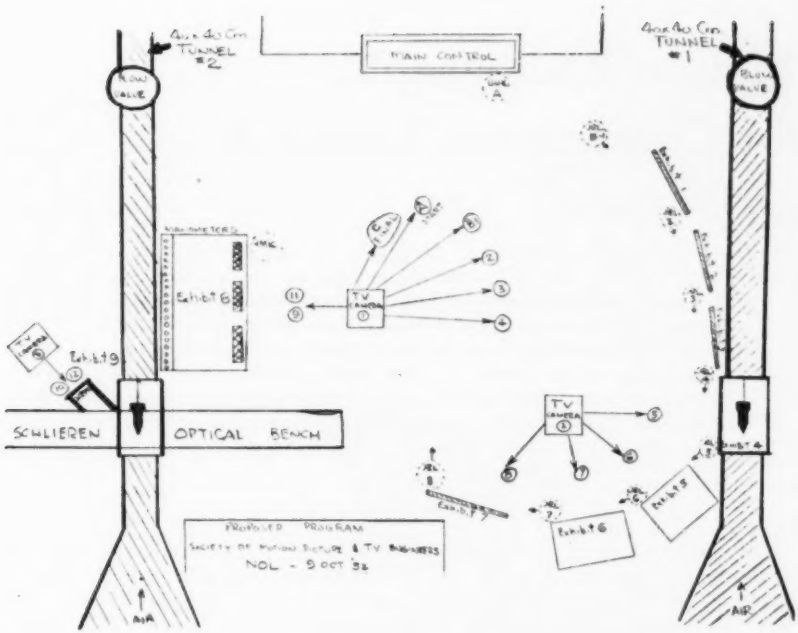
Supplied by Mary T. Kanagy, Public Information Officer, U.S. Naval Ordnance Laboratory, White Oak, Silver Spring 19, Md.

* For auditorium details see D. Max Beard and A. M. Erickson, "Auditorium specifically designed for technical meetings," *Jour. SMPTE, 59:* 205–211, Sept. 1952.


40×40 cm Tunnel (No. 2)
40×40 cm Tunnel (No. 1)
12×12 cm Aerophysics Tunnel (No. 6)
12×12 cm Internal Aerodynamics Tunnel (No. 5)
12×12 cm Heat Transfer Tunnel (No. 7)
12×12 cm Hypersonic Tunnel (No. 4)
18×18 cm Tunnel (No. 3)
Instrument Rooms
Main Control Board
Model Shop
Vacuum Sphere
Continuous Dryer
Auxiliary Dryer
Dryers
Offices
Vacuum Pumps
NAVAL ORDNANCE LABORATORY
SUBSONIC WIND TUNNELS



in most respects to Tunnel 1, had a similar model mounted in its working section and was actually operated.

After the test models of missiles had been displayed and basic instruments for measuring pressures, forces, and temperatures demonstrated, air was blown through Tunnel 2 at supersonic speed and a schlieren picture of the shock waves about the missile model was picked up on television camera 3 and telecast to the auditorium. At the same time the audience observed pressure-measuring instruments in actual use and saw much of the operation which would have been difficult to demonstrate to a large group of visitors even had a trip to the tunnels been possible.

The telecast concluded with a statement of planned improvements and future modernization of the plant, instrumentation and scientific techniques.

Motion Photography for Combustion Research

By F. W. BOWDITCH

The history of the use of semi-high-speed photography as a research tool for the study of the combustion process in gasoline engines at General Motors Research Laboratories is presented. The investigations consist of direct photography of the luminous combustion process as seen through quartz windows in the heads of several gasoline internal combustion engines. Both commercial cameras and cameras designed and built in these laboratories were used.

THE USE OF photography to study the combustion process as it occurs in a gasoline internal combustion engine was first successfully attempted[1] at the Research Laboratories Division of General Motors Corp. in 1930. Until then practically all information known about gasoline engine combustion had been obtained from pressure-time cards and from sampling valve studies. The results of the pressure card and sampling valve studies indicated that these methods alone could not completely describe the physical aspects of the combustion process.

It was decided that by taking photographs of the combustion process through a quartz window mounted in the head of a single-cylinder engine a physical picture of the combustion process could be obtained. Since the use of a quartz window in the head of an engine was entirely new, it was decided that a long, narrow quartz window would be the easiest to install and seal. Such a window 5 in. long and 0.375 in. wide was built into the head of a single-cylinder engine in a manner shown in Fig. 1. A film drum was mounted over the engine, with the axis of the cylinder parallel to the major axis of the quartz window, and a Meyer Plasmat $f/1.5$ lens was used to focus the quartz window on the drum. The drum and a focal-plane type shutter were driven from the camshaft of the engine in a direction normal to the direction of flame travel in the engine. The engine and camera equipment are shown in Fig. 2. Eastman Portrait Panchromatic cut film was wrapped around the drum, sufficient circumferential drum space for the film being provided so that enough film for one explosion could be used at a time. Examples of knocking and nonknocking type of flame record obtained are the upper parts of Fig. 3. Photographs of the ignition sparks appear at A and of timing sparks at B, 20° later. The flame photographs were taken with the film moving toward the left and the

Presented on October 9, 1952, at the Society's Convention at Washington, D.C., by F. W. Bowditch, Research Laboratories Division, General Motors Corp., Detroit 2, Mich.

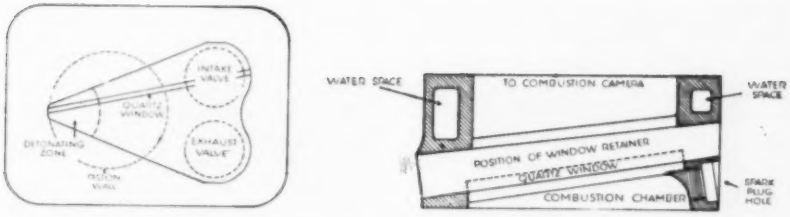


Fig. 1. Views of the cylinder head, showing the location of the quartz window and the general shape of the combustion chamber; left, plan of the ceiling of the combustion chamber; right, longitudinal section of the cylinder head.

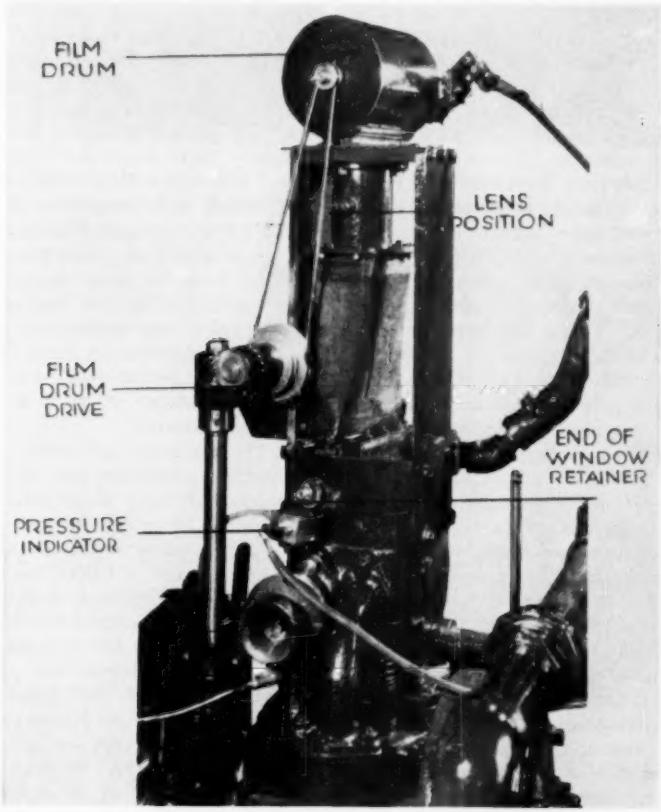


Fig. 2. The first combustion camera mounted upon the engine.

flame moving from the bottom to the top of the photographs. The upper sloping edge of the light portion was therefore a time-distance plot of the flame front movement across the combustion chamber. The region marked afterglow in the photographs was produced by the burned but luminous gas behind the flame front.

It was from these researches that it was definitely determined that normal combustion in a gasoline engine was initiated at a single point — the spark discharge — and spread from this point like a grass fire at a rate which could be determined from the slope of the pictures similar to the flame records of Fig. 3. It was also found that during the combustion process there is a relatively narrow zone in which all of the combustion process takes place and which moves progressively through the charge.

From this type of record it was found that flame speed is proportional to engine speed and that knock in a gasoline engine consists of the last part of the charge burning at a rate many times that occurring under normal combustion conditions. This is illustrated by comparing the flame records of Fig. 3. So it was that the first photographs of the burning of gasoline and air in a spark ignition engine furnished many of the basic facts which are now used daily in the design of better automobile engines.

This type of photography was limited, however, particularly in regard to determining the shape, structure and movements of the flame fronts and the nature of knock. In particular it was hoped that flame photographs would supply information regarding the effect of engine speed, chamber shape, fuel types, etc., on the rate of flame travel. These considerations led to the development of another engine which allowed an unrestricted view of the entire combustion chamber. The head and cylinder block are shown in Fig. 4. The problem of sealing the quartz window in the head frame required many hours of research. The problem facing the investigators at the time the original plans for the engine were drawn up was what type of camera could best be used for taking photographs of the combustion process through the full quartz head.

At this time a number of high-speed camera designs were available in the literature; however, careful consideration of the following aspects of the photographic problem showed that many of these cameras would be unsuitable:

1. The subject to be photographed was self-luminous; that is, the light was emitted from the flames themselves. This imposed a severe limitation upon camera design from an exposure standpoint and ruled out those cameras which depended upon a separate high intensity source of illumination.

2. The picture frequency had to be relatively high since the flame front moved at a high velocity from the spark plug across the combustion chamber. Under normal operating conditions at an engine speed of 2000 rpm a frame speed of 5000 frame/sec was required in a combustion chamber 5 in. long to obtain 20 pictures of the combustion process. At 400 rpm, however, a frame speed of only 1000 frame/sec was required for the same number of pictures of the combustion process.

3. The available light was fixed by the engine conditions and could not be varied at will. Experiments with the original flame camera showed that satisfactory results could be obtained with an exposure of 0.0002 sec and an engine speed of 1200 rpm, with an $f/1.5$ lens using a hypersensitive panchromatic film. Consequently, the light emitted by the combustion process was sufficient for frame speeds of 5000 frame/sec at an engine speed of 2000 rpm provided the duration of exposure was comparable with the time interval between frames and provided the lens speed was $f/1.5$ or greater throughout most of the exposure. In order to fulfill these condi-

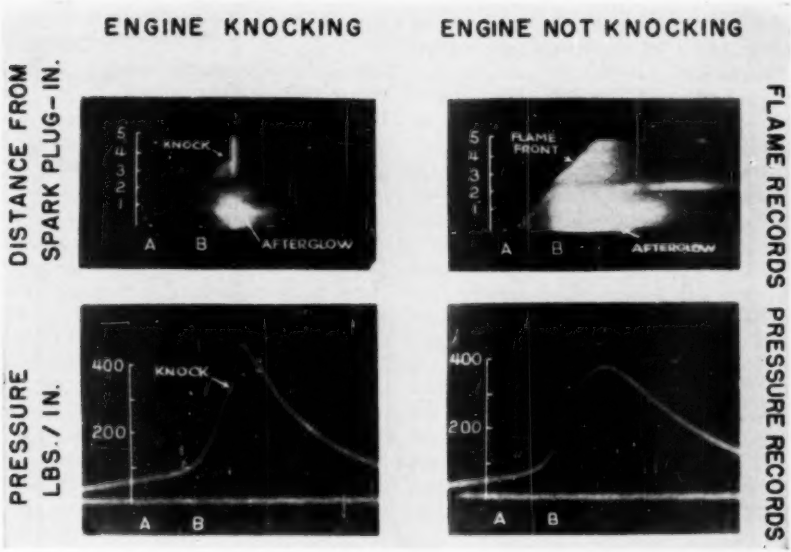


Fig. 3. Pictures show the effect of knock on the flame and pressure records; A, time of ignition; B, 20 deg after ignition.

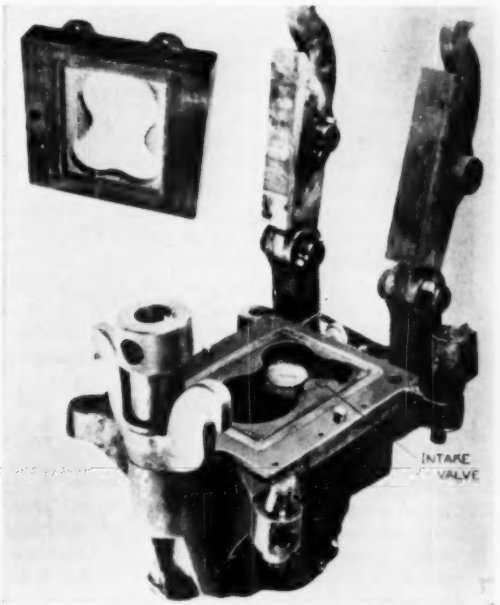


Fig. 4. Photograph of the head and block of the full-view quartz window L-head engine.

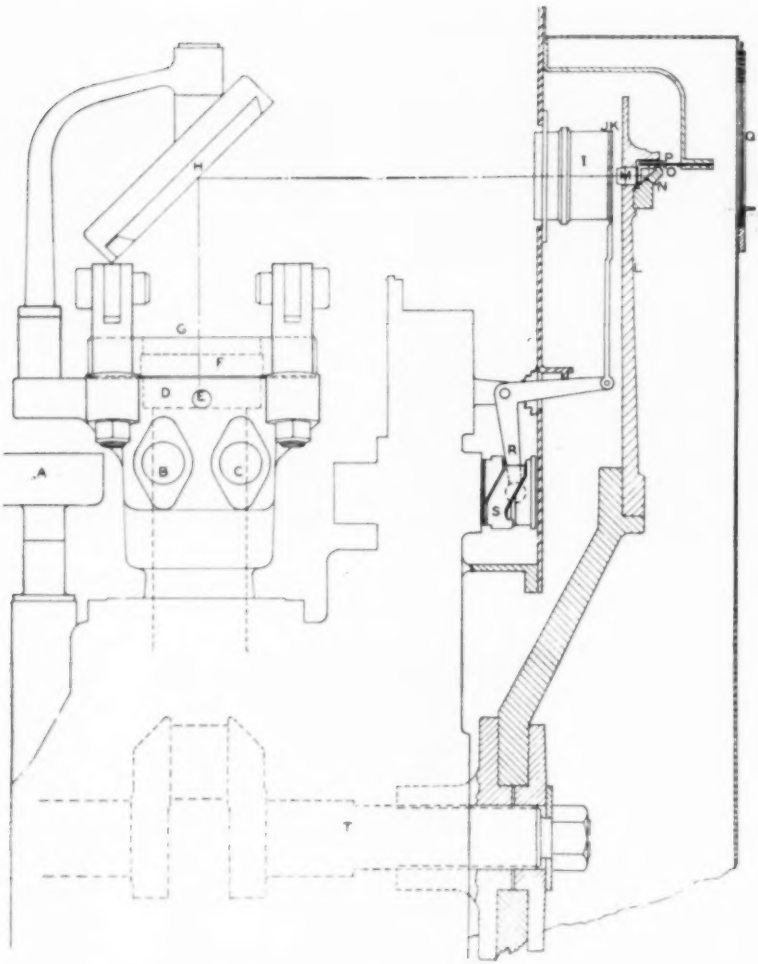


Fig. 5. Schematic drawing of camera.

A. Ignition breaker
B. Intake port
C. Exhaust port
D. Combustion chamber
E. Spark plug hole
F. Quartz window
G. Invar window frame
H. Stellite mirror
I. Stationary field lens
J. Lens stop
K. Shutter
L. Rotating disk
M. Moving lens
N. Prism
O. Focal plane shutter
P. Film
Q. Door in light-tight housing
R. Cam follower which actuates shutter
S. Shutter cam
T. Crankshaft

tions the film and image had to be moved together.

4. In order to obtain the minimum amount of blurring due to the rapid movement of the combustion process, it was necessary to utilize the shortest possible exposure time. Since light intensity could not be varied at will, the other alternative was to maintain a maximum lens speed during the entire exposure. This type of operation is approximated with the use of a focal plane shutter.

5. The picture could not be so small as to lose the details of the combustion process. A standard 16mm frame was chosen as the smallest suitable picture size. 16mm pictures taken at 5000 frame/sec require a minimum film speed of 38 meters per second.

6. In order to make full use of the flame pictures the angular position of the crankshaft during the exposure had to be known. Similarly, the gas pressure in the combustion chamber had to be known at the same angle and in the same explosion for each picture.

7. Simplicity of construction was an important consideration that need not be expanded upon here.

Of the optical systems available at the time, the system suggested by Wedmore[2] seemed more nearly to fulfill the qualifications than any other. A camera incorporating these principles was built into the flywheel of the engine and is shown schematically in Fig. 5. Light from the combustion chamber, D, passed through the quartz window, F, and was reflected by the stellite mirror, H, into a stationary field lens, I, (a Zeiss Opal Tessar). The principal plane of the field lens was in the combustion chamber. The beam of parallel rays formed by the field lens passed through each of a series of small lenses, M, as they were moved through this beam of light by a large circular disc attached to the crankshaft and rotated in a plane perpendicular to the plane of the paper. Light from the series of lenses, M, was reflected by a corresponding number of right-angle prisms, N, also mounted on the disc and located one behind each small lens as shown in Fig. 5. Images of the flames inside the combustion chamber were formed upon the film, P, which was held against the inside surface of the rim of the disc by centrifugal force. With such a system, the image of a stationary object in the combustion chamber remains at rest with respect to the moving film (except for a slight twisting motion) despite the motion of the 30 small lenses. The duration of exposure of each picture was controlled by varying the width of the stationary aperture, O, which was close to the film and acted like a focal-plane shutter. Another shutter, K, was provided with the necessary actuating mechanism so that exposure would take place through only one revolution of the disc.

The moving lenses were $f/2$ motion picture camera objectives purchased from the Eastman Kodak Co. The focal lengths were closely matched, but slight differences could be compensated for by individual adjustment of the position of each lens in the large disc. The lenses were spaced 2.4 crankshaft degrees apart, therefore 5000 frame/sec could be obtained at an engine speed of 2000 rpm and adequate exposure obtained by adjusting the focal plane shutter to give an exposure of 2.2 crankshaft degrees for each picture or $91\frac{2}{3}\%$ of the time between frames.

It is interesting in this connection to calculate the amount of light lost in this optical system. The stellite mirror, H, Fig. 5, scattered about one-half the light incident upon it. The amount of light lost by Fresnel reflections at the glass-air surfaces of the rest of the optical system may be approximated from the equation

$$t = \left[1 - \frac{(n-1)^2}{(n+1)^2}\right]^k$$

where t is the total transmittance if

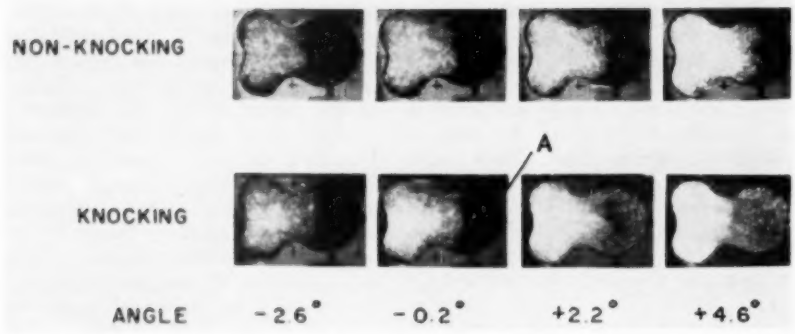


Fig. 6. Full-view flame pictures which distinguish between knocking and non-knocking combustion; four frames on left are before top dead center, and four frames on right are after top dead center.

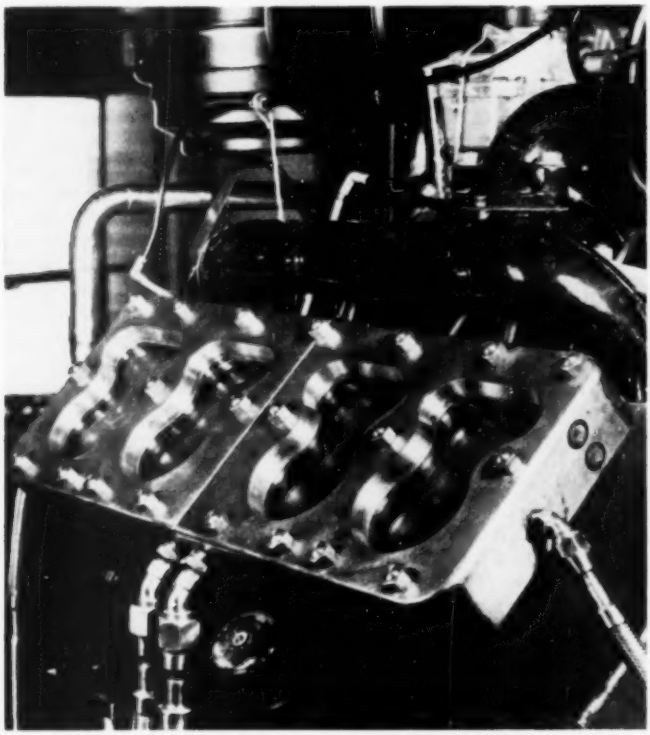


Fig. 7. 1939 Cadillac engine with quartz-window heads on left bank.

absorption is neglected, n is the refractive index of the optical glass, and k is the number of glass-air surfaces. Since the refractive indexes of optical glass in common use lie between 1.5 and 1.7, the average value of $(n-1)^2/(n+1)^2$ is about 5% and the transmittance can be computed with reasonable accuracy[3] as $t = (0.95)^k$.

The high-speed camera optical system consisted of 16 glass-air surfaces since both the field lens and the moving lenses were multicomponent lenses. The amount of transmitted light, therefore, through the lens system and prisms amounted to 44% of the incident light not considering that lost at the stellite mirror. Therefore, since about 50% of the light was lost at the stellite mirror, the approximate total transmitted light was about 22% of the incident light. If all the glass-air surfaces had been coated, as is now current practice, the approximate total transmittance would have been about twice as much or 44%. The present-day Eastman High-Speed Camera Model III, a rotating-prism type camera, having a coated Ektar lens and an uncoated prism can be used without the large stellite mirror mounted over the engine head and the transmittance of this optical system is approximately 83%. The older ERPI Camera (Electrical Research Products, Inc.) with uncoated optics, another rotating-prism type of camera, without the engine stellite mirror had a transmittance of about 73%.

Since the ERPI exposure time amounted to about 25% of the time between frames and the engine camera to about 90% of the time between frames, the total amount of light reaching the film per frame at the same frame speed in the two cameras was about the same due to the total transmittance difference of the two cameras. Experimentation with an ERPI camera since the engine camera was built has shown that even though the flame front moved about three-and-one-half times as far per exposure with the engine camera as it did with the ERPI camera, photographs of about equal definition were obtained with the two cameras. This apparent anomaly may be at least partially explained by the distortion of the images in the rotating-prism cameras due to the motion of the prisms.

Returning to the combustion photographs obtained with the engine high-speed camera, unrestricted views of nonknocking and knocking explosions were taken. The knocking explosion pictures revealed in a most striking manner the occurrence of spontaneous ignition in sections of the unburned charge well ahead of, and completely separated from, the advancing flame front. Figure 6 illustrates this difference between normal or nonknocking combustion and knocking combustion.

From similar pictures and corresponding pressure records Drs. Withrow and Rassweiler[4] were able to sort out pressure changes due to combustion from those due to piston motion on the pressure records and found very important relations between per cent of pressure rise and per cent of fuel-air mixture burned. They were also able to determine the effects of changes in mixture ratio, spark position and throttle opening upon the combustion process — all very important to the operation of our modern automobile engines.

In 1939 interest was revived in a combustion phenomenon known as "after-running" (tendency for engines to continue running at very low speeds after ignition has been shut off). At this time a 1939 V-8 Cadillac engine was made available to these Laboratories and quartz windows were mounted on the left bank affording an unrestricted view of the combustion chambers in these four cylinders. This engine with the quartz windows in place is shown in Fig. 7. This engine may be familiar to the reader since it was later exhibited at the New York World's Fair.

In this investigation it was necessary

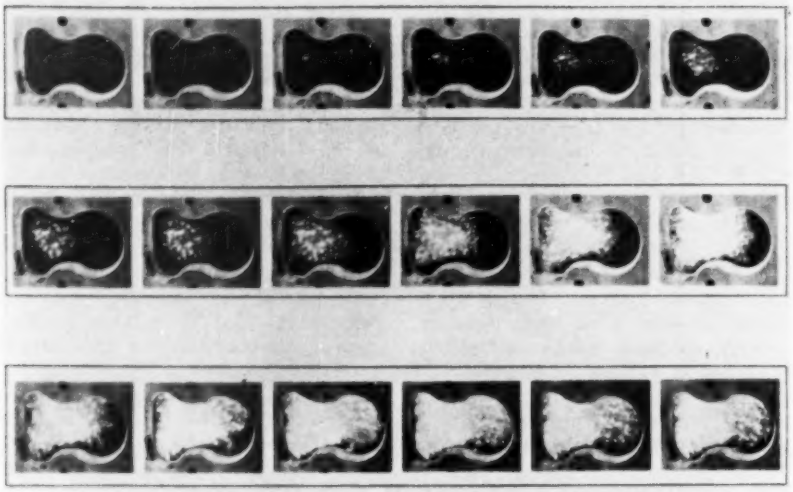


Fig. 8. Flame pictures of combustion in cylinder four of Cadillac window engine during after-running; engine speed 260 rpm; throttle partially open; ignition spark cut off; compression ratio 5:1; 60-octane secondary reference fuel; intake at top and exhaust at bottom of each picture; 18 successive frames taken at rate of 1140 frames per second.

to obtain photographs of *consecutive* explosions as they occurred in the engine. Therefore it was not possible to use the high-speed camera principles as outlined by Wedmore and used in the previous window engine since the old engine camera was capable of taking pictures of only one explosion. The ERPI high-speed camera was used. In this camera the field lens focuses the image on the continuously moving 16mm film. Between the lens and the film a glass plate, or two-sided prism, is rotated in such a way that the image is made to move with film. In order to assure complete synchronization of the film and the image, a single motor is used to drive both the film and the prism. A complete discussion of the operation of this camera may be found in the literature.[5]

Eastman Kodak Super XX film and its standard developing procedure were used. Speeds were about 1150 frame/sec and engine speeds were approximately 260 rpm. The engine ignition system was shut off. Photographs were taken of two adjoining combustion chambers simultaneously with no effort being made to determine the crankshaft angular position for each photograph. Figure 8 is an example of the photographs obtained for one explosion in one of the combustion chambers. This investigation revealed the important fact that "after-running" was not due to hot spots in the combustion chamber since consecutive explosions showed that combustion was never initiated at the same point in the combustion chamber in any two explosions. The exact mechanism of this phenomenon is still not known.

The investigation of autoignition (ignition by means other than the spark plug discharge) was reopened in 1943. At that time interest in the problem was quite high because of a general occur-

rence of field complaints. For this investigation the original full-view window engine (see Fig. 4) without the camera attachments was used. The ERPI camera was used again with 16mm Super XX motion picture film since photographs of consecutive explosions were again required.

It was necessary in portions of this investigation that the angular position of the crankshaft for each photograph be known since the photographs were to be used in connection with pressure card data. A double-lobed cam was used on the distributor so that the spark plug (which was in the field of the camera) would fire twice, once to initiate combustion and again 90 crank-angle degrees later for a timing mark. These spark discharges did not always appear on the film because they would sometimes occur entirely during the two-thirds of the time the film was not being exposed. By using the built-in ERPI timer and those spark discharges which were available, it was possible to determine the average time in crank-angle degrees per frame and so determine the angular position for each photograph. Similar calculations were made on the time axis of the pressure records so that the photographs and pressure records could be related. It is interesting to note that the speed of the engine could be found more accurately from the flame photographs than with the available engine instrumentation due to the electrical timer built into the ERPI.

For orientation purposes the metal frame around the quartz window was illuminated with 120-w photoflood lamps. These lamps were used at shallow angles of incidence to the head of the engine so that the combustion chamber itself was not illuminated. This frame outline on each photograph provided the necessary reference points for the orientation of the random centers of ignition which occur during autoignition.

In this autoignition investigation various types of engine deposits were accumulated with a full metal head on the engine. The engine was then stopped and the quartz head substituted for the metal one. Pictures of the combustion process in the presence of the deposits were taken shortly after the engine was restarted. Ordinarily the engine with the quartz head could be run for only short periods of time with deposits in the combustion chamber since the deposits became detached from the combustion chamber walls and were deposited on the quartz window. By taking photographs of consecutive explosions as they occurred in the presence of various deposits, some very important effects of combustion chamber deposits upon the combustion process were determined.

Interest was again revived in the subject of autoignition in 1951 since autoignition rather than knock became one of the most important considerations in attempting to increase the performance of automobile engines. The original full-quartz-head window engine, now 21 years old, was again used at the beginning of this investigation which is now in progress.

Four changes have been made in the procedure used in 1943. The first was the substitution of an Eastman Model III High-Speed Camera for the older ERPI camera. The basic principles of operation of the two cameras are the same but improved methods of operation are incorporated in the newer camera. A complete description of this camera may be found in the literature.[6]

Second, since stiffening blocks had been added to the top surface of the window frame, the angle of incidence of the illumination from the flood lamps used to light up the frame around the quartz window had to be increased. In so doing some of this light illuminated portions of the combustion chamber making definition of the combustion process in these areas difficult. There-

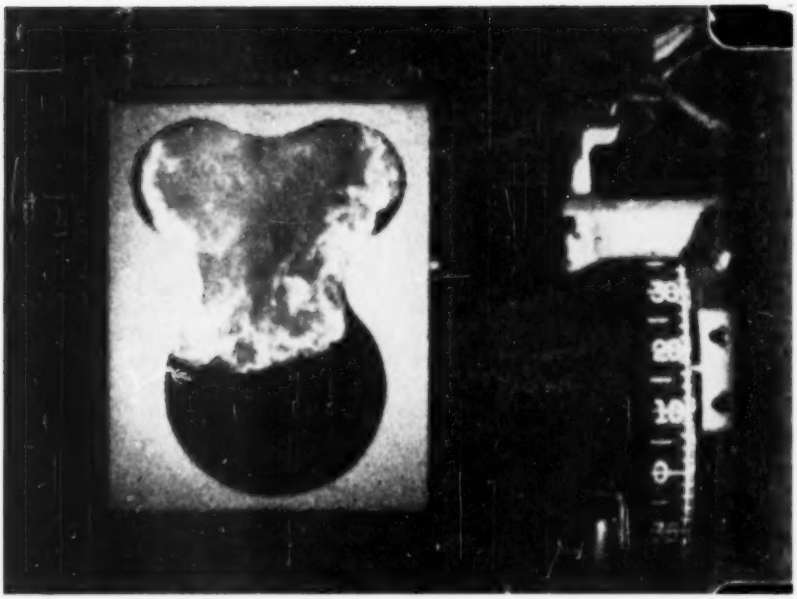


Fig. 9. 16mm frame showing the flywheel at the right and the fluorescent window frame.

fore, the top of the window frame was painted with blue fluorescent sign paint and illuminated with ultraviolet light from three General Electric 100-w E-H4 projector flood lamps operated on direct current using filters similar to Corning filter color specification 739 which confined most of the illumination to ultraviolet wavelengths. This method gave sufficient visible light from the window frame but did not affect the pictures of the combustion process.

The third major change from previous operating procedure was the use of Eastman Kodak Linagraph Pan 16mm film in place of Eastman Kodak Super XX film. This was done because of the exceptional blue sensitivity of this new film and the predominance of blue light given off by the combustion process allowing shorter exposure times to be used.

The fourth and perhaps most important change in procedure was the method used to determine the angular position of the crankshaft at which each picture was taken. This was done by replacing the $f/2.7$, 63-mm focal-length lens with which the camera was equipped with an $f/1.9$, 25-mm focal-length lens. The shorter focal-length lens provided a sufficiently great depth of focus so that when the combustion chamber of the engine was in focus the flywheel of the engine which was about seven inches further from the camera than the combustion chamber remained well enough in focus so that the degree divisions on the flywheel could readily be seen. Even though the shorter focal-length lens reduced definition, the photographs were sufficient for this study. The rim of the flywheel was painted a dull black and the degree divisions and numbers white. At frame speeds of 2000 frame/

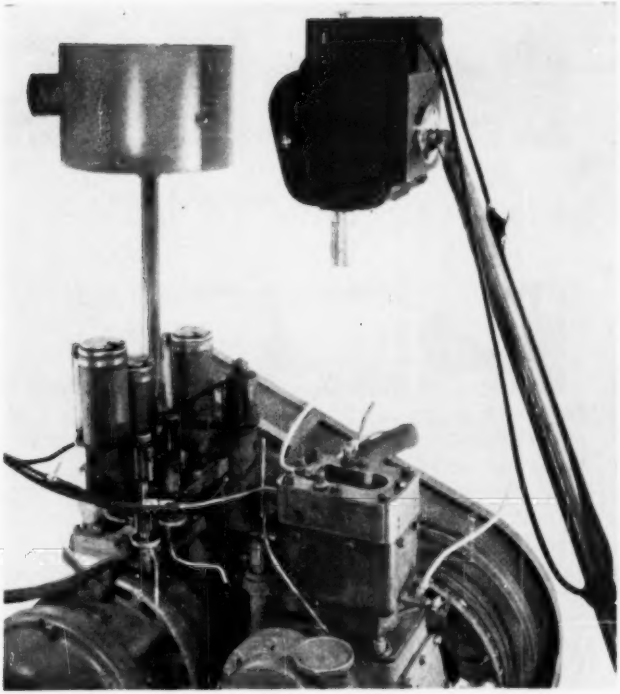


Fig. 10. Eastman Camera and CFR L-head engine fitted with quartz window.

sec and flywheel rim velocities of about 47 ft/sec the numbers and degree division marks were sufficiently clear that readings to the nearest one-half crankshaft degrees could be made on each picture. An example of the results obtained by using the fluorescent frame, the Linagraph Pan film and the short focal-length lens is shown in Fig. 9.

When the opportunity presented itself in 1951 a newer engine more nearly like the modern automobile engine was equipped with a quartz head (Fig. 10). The work on autoignition was transferred to this engine with three alterations in the photographic procedure. First, since the head of the engine was unobstructed, photoflood lamps could be used at shallow angles of incidence to illuminate the quartz frame. Second, the flywheel division marks were made narrower and longer allowing the crankshaft angular position for each frame to be determined within 0.1°. The third change in photographic procedure was brought about by the desire to obtain both motion pictures of the combustion process and, simultaneously, oscilloscope pictures of the pressure records of the combustion processes. A Fairchild oscilloscope camera was used to take the oscilloscope pictures and, in order to relate the pressure records to the corresponding engine combustion process, both a small incandescent lamp in the oscilloscope camera and a 40-w incandescent lamp in the field of view of the high-speed camera were flashed simultaneously. By having one explosion related, the remainder of the two films

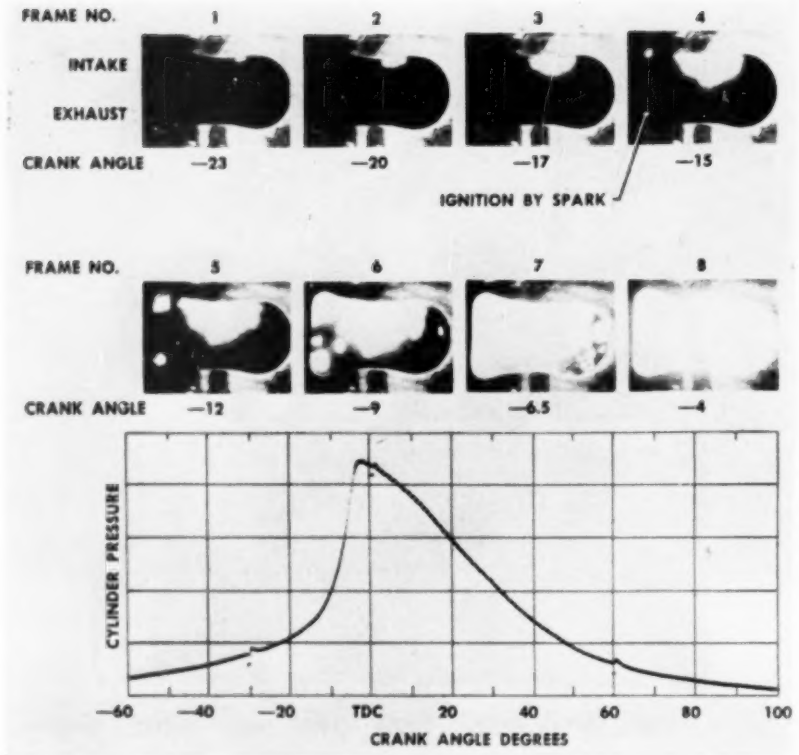


Fig. 11. Flame pictures and corresponding pressure card of preigniting explosion; engine speed 900 rpm; throttle fully open; spark advance 16 deg before top dead center; air-fuel ratio 13:1; compression ratio 6.8:1; 70-octane number reference fuel.

could be correlated readily. Figure 11 illustrates the type of record obtained by this process. This engine and photographic procedure is being used at the present time as a tool in the continuing research on our modern automobile engine.

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Accuracy Limitations on High-Speed Metric Photography

By AMY E. GRIFFIN and ELMER E. GREEN

Parameter limits in high-speed camera design and physical characteristics of photographic images limit the assessment accuracy of high-speed metric film records. The errors in film measurements range from 2 to 75 microns. Proper design of field instrumentation is required to minimize effects of reading errors in a measurement system for ballistic data.

Uses of Metric Cameras

The measurement system on the ground ranges at the U.S. Naval Ordnance Test Station, Inyokern (NOTS), was designed primarily to obtain ballistic data on rockets and guided missiles. High-speed photography, which is here defined as photography at more than 500 frame/sec, is a useful tool for studying missile flight phenomena such as flame characteristics but is seldom applicable to the study of ballistic parameters which are derived from missile trajectory and attitude data. High-speed cameras are not useful for these purposes because, in general, their accuracy limitations are too severe to permit their use at their high frame rates as metric instruments, i.e. instruments from which data such as velocity, acceleration and direction of motion (which are usually obtained by differencing successive position determinations) can be obtained.

If an unsuccessful missile flight is caused by factors inducing vibrations or moments resulting in instability, the first photographic evidence of this may be some physical change in the missile such as the breaking of a stabilizing fin. To pinpoint the time of this occurrence photographically to desired accuracy may require frame speeds of 1000 per sec or higher, but a mere determination of the moment of failure is inadequate for flight analysis. In addition to knowing the exact time of failure it is necessary to study closely the behavior of the missile previous to this time to determine whether the fin was substandard or whether the failure was caused by unexpected stresses on the fin. If the latter is the case, data are required to determine whether the unexpected stresses were caused by aerodynamic forces larger than anticipated or by inability of the missile to achieve flight stability under the anticipated conditions.

Presented by Amy E. Griffin on October 9, 1952, at the Society's Convention at Washington, D.C., by Amy E. Griffin and Elmer E. Green, Assessment Div., Data Reduction Branch, U.S. Naval Ordnance Test Station, Inyokern, China Lake, Calif.

Table I

Camera type	Shutter type	*f*/stop	Focal length, in.	Frame speed, expos./sec	Frame size, mm	Expos. time, msec	Film movement during expos., mm
Askania Cine-Theodolite	Venetian blind	6.3	24	4	37 × 27	6	None
		8.0	6	32	25 × 18	10	None
Mitchell	Rotating sector	8.0	48	64	25 × 18	5	
		25 with 21 filter	120	48	25 × 18	7	
Bowen Ribbon Frame	Revolving drum slit	5.6	10	30 to 180	133 × 24 to 133 × 4	0.1 to 0.03	0.068 to 0.023
General Radio	None (Edgerton Flash)	2.8	4	1000 to 7000	26 × 8 to 26 × 4	0.001	0.009
Fastax	Rotating prism	2.0	2	2500 to 4000	25 × 9 11 × 4	0.10 to 0.06	0.04* to 0.06

* Compensation by rotation of prism eliminates most effects of film movement.

The photographically obtainable data which are required to determine the cause of failure are the missile velocity, acceleration, direction of motion and attitude. From the difference between the attitude of the missile and its direction of motion can be determined the direction in which aerodynamic forces are applied to the fins. From the missile velocity and acceleration can be determined the magnitude of the forces. The direction of the force may be needed to an accuracy of $\pm 0.1°$ or better. The acceleration may be required to an accuracy of ± 1 G.

To obtain free-flight data with the above accuracy at rates of 1000 frame/sec would require impossible accuracies in position determinations. Random errors of ± 0.00001 ft in position would result in an error of ± 1 G in accelerations obtained by differencing of position data from successive frames.

Using specially designed cameras, it is often possible to hold random errors in missile position determinations to approximately ± 0.04 ft. When position determinations are held to this accuracy, frame rates in the order of 20 per sec result in acceleration accuracies of ± 1 G. If long focal length lenses are used with these special cameras or if the cameras can be placed close to the flight line, random missile position errors in the order of ± 0.001 ft can be obtained. Frame rates of 90 per sec can be used with this position accuracy to obtain ± 1 G acceleration accuracy. This accuracy, however, can be achieved only with such cameras as the Bowen Ribbon Frame camera and then only if the film can be read to an accuracy of ± 2 microns.

Camera Parameters

Some of the cameras in use at NOTS are standard high-speed machines but others such as the Bowen ribbon frame cameras[1] and Askania Cinetheodolite[2] were originally designed for metric purposes. Table I compares their operating characteristics. The table does not include all cameras in common use at NOTS but merely gives single examples of each type. Likewise, only the most frequently used lens-and-shutter combinations are given.

These cameras differ widely not only in their operating characteristics but in the accuracy limits for data obtained from them. In determining the accuracy limitations of a camera and consequently its usefulness as a metric tool, the following factors are considered:

1. resolving power,
2. accuracy with which the lens and film orientation can be determined, and
3. accuracy with which the time of exposure of the missile can be determined.

Resolving power is considered here as the resolving power of the lens and film combined when photographing missiles under usual lighting. The resolving power is then defined as the reciprocal of twice the diameter of the finest line that can be resolved on the film under these conditions. Expressed mathematically

$$R = 1/2w \qquad (1)$$

where R is resolving power in lines per millimeter and w is the width of the line in millimeters.

This definition is essentially in agreement with standard methods of determining resolving power with the exception that this is the resolving power under ordinary medium contrast, not with high contrast. Since high contrast in the negatives is rarely possible, the use of a resolving power based on that condition is invalid.

Resolving power is linked to accuracy in missile position in the following way. It has been experimentally determined that a line of medium contrast to the general background can be bisected to an accuracy of about 1/20 its width. Thus (using standard film-measuring devices) an operator can bisect a reference line and the missile line on the

film and record their coordinates. If both the reference line and the line on the missile are the finest lines resolvable, the standard error in the distance from the reference to the missile will be equal to $\sqrt{2}/20$ the width of each line (this allows for errors on both measurements).

Expressed mathematically

$$A_f = \sqrt{2}w/20 \qquad (2)$$

where A_f is the standard reading error in millimeters on the film and w again is the width of the finest resolvable line in millimeters.

By substitution of Eq. 1 in Eq. 2

$$A_f = \sqrt{2}/40R \qquad (3)$$

If the camera is to be used as a tracking camera, Eq. 3 is sufficient because if the resolving power is too low to give sufficient reading accuracy, a longer lens can be used so that reading errors result in correspondingly less error in missile position determination.

If the camera is not used to track the missile but has a fixed coverage, then reading accuracy must be considered in terms of the coverage desired with this camera. Essentially, the data desired are acceleration values, but since these are obtained by differencing two velocity values which in turn are obtained by differencing two position values, it is always necessary to obtain two more frames including the missile than the number of acceleration values desired from this one camera. Also the relation between reading accuracy on the film and acceleration accuracy must be defined.

If only position errors are considered it can be shown that

$$A_a = A_s\sqrt{6}/T^2 \qquad (4)$$

where A_s is the standard position error of the missile in feet,

A_a is the standard acceleration error in feet per second squared,

A_s is the standard position error of the missile in feet, and

T is the time between successive frames in seconds.

But if the width of the frame in the direction of rocket travel is W_f in millimeters and the distance in feet in space that this film covers is W_s, projecting film readings into space:

$$W_f/W_s = A_f/A_s \qquad (5)$$

Substituting Eq. 5 and Eq. 3 in Eq. 4:

$$A_a = \sqrt{3}\ W_s/20W_fRT^2 \qquad (6)$$

W_s, the distance covered along the trajectory, is a function of the focal length of the camera and the distance from the camera to the missile, but since, n general, the focal length and camera distance can be varied, it is more useful to consider the distance in terms of the coverage desired. If the average velocity of the missile as it passes the camera is V and S is one less than the number of frames in which the missile is exposed, then:

$$W_s = VST \qquad (7)$$

where T again is the time between successive frames.

If Eq. 7 is substituted in Eq. 6

$$A_a = \sqrt{3}\ VS/20\ W_fRT \qquad (8)$$

Since there must be two more frames than the number of acceleration values and S is always one less than the number of frames in which the missile is exposed, S is always one greater than the number of acceleration values. If Eq. 8 is written in terms of both the acceleration error and the number of acceleration values desired and converted to G's,

$$A_a/S = \sqrt{3}\ V/640\ W_fRT \qquad (9)$$

Since Frame Speed (*F.S.*) is the reciprocal of T, the time between frames

$$A_a/S = \sqrt{3}\ VF.S./640\ W_fR \qquad (10)$$

If the acceleration error (A_a) is required to be less than one G and if only one acceleration value is required (which makes $S = 2$), for a velocity of 1000 fps and a resolving power of 10

Table II. Errors of Missile Exposure Time.

Camera type	Shutter type	Modifications to original camera	Random errors in time, μsec
Askania	Venetian blind	Camera dials illuminated by Edgerton Flash Lamps	3000
Mitchell	Rotating sector	Binary timing	300
Bowen	Rotating drum slit	Finer slits in drum; 1000-cycle timing pulses on film	3
General Radio	None (Edgerton Flash)		0.1
Fastax	Rotating prism	1000-cycle timing pulses on film	20

lines/mm, the highest frame speed over which acceleration data can be obtained with 35mm film would be 70 frame/sec.

In general, 5 to 10 acceleration values are desired from each camera. As a result, the Bowen cameras are used with the centerline of the 125-mm frame set approximately parallel to the portion of trajectory to be covered. On Bowen Film $R = 10$ lines/mm under most conditions. This value of R is low because of the movement of the missile image and the film during exposure.

So

$$A_a/S = V \times F.S./452{,}500 \qquad (11)$$

If A_a is 1 G, $S = 10$ and $V = 1000$, the highest usable frame speed is 45 per second. Data are usually obtained at the rate of 10 per sec or 30 per sec from Bowen cameras since missile velocities may be larger than 1000 fps.

But resolving power is not the only factor determining the accuracy of acceleration values. Under many conditions, it is necessary that the camera track the missile, so the accuracy with which the orientation of the lens and film can be determined is also important. With present camera mounts these orientations can be determined no better than ±1 minute of arc and since high missile velocities require that the cameras be located some distance from the flight line in order that the operator can track the missile, these cameras have random errors in missile position of the order of 1 to 3 ft. This invalidates the use of high frame rates for ballistic purposes.

Even for cameras which do not track the round, it is necessary to determine the camera orientation to a fairly high accuracy because errors in this orientation introduce bias errors in the data. The ±1 minute of arc accuracy obtainable is sufficient to make bias errors inconsequential.

Besides resolving power and camera orientation there are still errors in the time of exposure of the missile. Consider the following example: If a missile is traveling 1000 fps, to determine its position to ±0.01 ft the time of missile exposure must be known to the nearest 10 μsec.

The errors in time of exposure of the missile as best determined for the cameras in common use are given in Table II.

In general these errors in time of missile exposure have a random error effect on the accuracy of velocity and acceleration data. When cameras are used to track missiles, timing errors are inconsequential if the tracking is smooth. The 3000-μsec error in Askania timing does not affect the accuracy of velocity and acceleration data if the operator is able to keep the missile in the center of the frame. But if he is not able to do so, the tracking error measured on

the film may not be the true tracking error at the time of exposure of the dials from which the azimuth and elevation angles of the camera are determined. If the angular error in tracking is greater than 3° per sec, timing errors appreciably affect the accuracy of the data.

A study of Table II indicates that in some cases the time of exposure can be determined very precisely. Often this cannot be done without studying the camera design and measuring some of its components. For a camera such as the Bowen it is necessary to obtain the dimensions of the shutter drum, shutter slit, and film drum and to measure the revolution rate of the shutter drum, the film speed, and the position of the missile in the film. This and other corrections to Bowen Cameras have been investigated previously.[3]

These, then, are the tools available for recording photographic data of missile flights. The Bowen and Askania cameras are used to obtain the greater part of metric data. The higher speed cameras are relegated to uses such as determining flame characteristics, for which they are better fitted. Data describing high frequency changes in missile behavior can be obtained only through use of metric electronic equipment. Since electronic equipment cannot be used under many conditions, it is essential that each camera be used in such a way that the utmost accuracy from that camera is obtained and the highest significant frame rates can be used.

Instrument Usage

The problem of using each camera at its maximum efficiency by making use of its good points and minimizing its weak points has been met at NOTS in the following ways:

1. Determine the sources of errors in each camera.
2. Modify cameras where possible to eliminate errors.
3. Determine the magnitude of those errors that cannot be eliminated conveniently by modification.
4. Use the camera in a location and manner which minimize the effects of remaining errors.
5. Have sufficient records to make it possible to overdetermine each trajectory point.
6. Apply statistics to obtain a satisfactory approximation of the trajectory point in question.
7. In terms of the solution obtained in item 6 above check the determination of errors from each camera (item 3) and also obtain an evaluation of the test data.
8. On a long term basis, design cameras which will have the characteristics required.

The development and use of Askania Cinetheodolite cameras exemplify the method of accounting for camera errors. The cameras were built and used by the Germans to obtain aeroplane flight data. For this use neither high frame speeds, high shutter speeds, high tracking rates nor good synchronization between the dials and the picture was needed.

In planning to use these cameras for missile flight data it was immediately obvious that the tracking rates would have to be increased. This was accomplished by eliminating the gear-drive making them free-sliding on their bearings. Since exposure of the dials indicating camera orientation was not well synchronized with the main shutter, better synchronization was achieved by illuminating the dials with Edgerton flashlamps whose discharge was timed to coincide as far as possible (± 3 msec) with the opening of the main shutter. The high illumination and short exposure of the Edgerton flashlamps also effectively stopped the apparent motion on film of the azimuth and elevation dial readings.

With these modifications Askanias were installed as an integral part of the range instrumentation system. To minimize reading errors, the cameras were

placed as close to the flight line as the tracking rates and safety conditions would allow, and enough cameras were used to insure that at least three cameras would be photographing the missile at all times.

In reduction of data a method of least squares is used which permits the combination of data from any number of cameras simultaneously to obtain a solution. This method[2] permits weighing the data from each camera relative to its distance from the missile. The solution of missile position so obtained is, on the average, nearer to the true position than any other solution that can be computed. Since this solution minimizes the residual error from each camera, analysis of the errors from several flights permits a determination of the magnitude of the errors from each camera.

Checking the errors so determined over several tests indicated that some of them were not truly random. This led to an investigation of the azimuth dials and bearings and to the discovery that the dials were eccentric relative to the bearings. As a result, tests were designed to measure the eccentricity so its effect could be eliminated from the data during computation. At the present time, with all known corrections applied, missile position can be determined to an accuracy of ± 3 ft. This invalidates data obtained at high frame rates so the 4 per sec frame rate of the Askanias is adequate. For this reason they are used to cover those portions of the trajectory where changes in velocity and acceleration are slow, such as the afterburning flight of the missile. For documentary purposes, a Mitchell, Eastman High-Speed or Fastax camera may be used alongside the Askania at high frame rates to obtain documentary coverage simultaneously with the Askania data.

Experience in the use of Askania cameras has been incorporated in specifications for future tracking equipment with requirements as follows:

1. construction of a mount on which any one of several cameras can be mounted,
2. motor drive for the mount,
3. higher accuracy in the mount,
4. electrical circuitry permitting the starting of each camera automatically at a predetermined time in the missile flight,
5. longer and "faster" lenses, and
6. pulse operated or synchronously driven shutters.

The accuracies obtained with present Askania cameras using 24-in. lenses require only low reading accuracy. A reading error of 0.060mm results in an error of only 10 sec of arc in the determination of the direction of the line from the camera to the missile which, if the missile were 10,000 ft away, would result in a 1-ft position error. If future cameras are equipped with longer lenses, accuracies in missile position made possible with higher accuracies in the mount can be obtained with no greater demand on reading accuracies.

A study of the development of the Bowen ribbon-frame camera shows changes in its use and accuracy similar to that resulting from Askania use. Since this camera was designed originally for missile acceleration data, the changes have been more of degree than kind. Its present use and accuracy are limited principally by the resolution of the lens-film combination. Studies are underway to develop an $f/3.5$ lens with high resolving power for this camera. Since an $f/3.5$ lens would permit exposure times of the order of 10 μsec, blur on the film caused by image and film movement would be greatly lessened. It is expected that resolving powers of 20–30 lines/mm will be possible under these conditions.

Recently a 70mm camera has been developed[4] which can record at a rate of 450 pictures per sec. The film does

not move during the exposure so the resolving power of this camera may be high enough to validate data obtained at a 450 per sec rate.

In conclusion, the use of high-speed cameras for metric purposes illustrates a common experience — equipment well suited for one specific purpose may be entirely inadequate for a similar purpose. The extremely high frame speeds possible with the Fastax and Eastman High-Speed cameras are usually useless for metric ballistic purposes because of the accuracy limitations of the cameras and film. It has been necessary to design metric cameras with these accuracy limitations in mind and use them in ways that minimize their errors. Greater accuracies can be achieved only if emulsions and lenses can be developed which permit the use of shorter exposure times and which at the same time possess higher resolving power.

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Discussion

Dave Miller (Battelle Memorial Institute): I would like to get some confirmation of the apparent fact that your Askania data are correct within one to three feet, is that correct?

Mrs. Griffin: Yes. However, this depends on how far it is from the camera to the missile.

Mr. Miller: How far?

Mrs. Griffin: Within 10 or 15 thousand feet. The random errors in the azimuth and elevation angles measured with Askania cameras at the present time are of the order of one minute. There are also eccentricity errors in these cameras which can be corrected for but they seem to change with time, which makes it difficult to do so.

Mr. Miller: I wonder whether you could not release a number of flares with parachutes, so that several of them would always be within the field of view. They should move quite slowly, their motion should be substantially constant, and their motion could be computed, so that the positions of such flares as seen in the photographs could be used as a basis for determining the changes in azimuth and elevation, eliminating the need for dependence on the scales provided on the mounting of the camera.

Mrs. Griffin: We, at Inyokern, are right beside the Sierra Nevada Mountains. I don't know whether you have knowledge of the wavefronts there, but this region is where they do their experimental sail-plane flying. The wind velocities are of the order of 60 mph. They may change within 1000 ft and go in the reverse direction. I don't think it is practical.

Mr. Miller: Then possibly another site might be considered favorably.

High-Speed Cine-Electrocardiography

By JOSHUA J. FIELDS, LOUIS FIELDS, ELEANOR GERLACH and MYRON PRINZMETAL

This paper describes a method of using the high-speed camera in medical research on heart disease. Normal and abnormal human and animal hearts are photographed at high speed simultaneously with the electrocardiograph recording, to ascertain and to study the conditions revealed by similar electrocardiograms of human patients.

One of the most useful tools for studying the motion of the heart is the high-speed camera. For several years we have been taking slow motion pictures of the intact, beating heart of animals, before and after the experimental production of certain types of heart disorders. The magnification in time and detail has revealed much about the contraction not only of the whole heart but of the individual muscle fibres as well, in both normal and abnormal cardiac conditions. Careful analysis of these motion pictures has yielded a great deal of information concerning the mechanism and nature of heart action.

However, the clinical diagnosis of heart disease depends to a great extent upon what the electrocardiographic tracing reveals. In order to apply what we learned from the motion pictures to patients with heart disease, it was necessary to correlate the mechanical events of the heart with the electrical events. This meant, of course, recording the heart motion and the electrical trace simultaneously, and on the same film. In this way, corresponding mechanical and electrical events could be analyzed. After many trials and errors, a suitable technique was devised.

Presented on October 10, 1952, at the Society's Convention at Washington, D.C., by Ethel Foladare for the authors. This work is from the Institute for Medical Research, Cedars of Lebanon Hospital, 4751 Fountain Ave., Los Angeles 29, Calif., and the Department of Medicine, University of California Medical School, Los Angeles, Calif. This study was aided by grants from the L. D. Beaumont Trust Fund, the Blanche May Memorial Fund, the Margaret Mayer Fund, L. Spitz, I. Berlin and E. Mannix.

Procedure and Equipment

Figure 1 illustrates diagrammatically the relative positions of the equipment used. The camera is focused directly

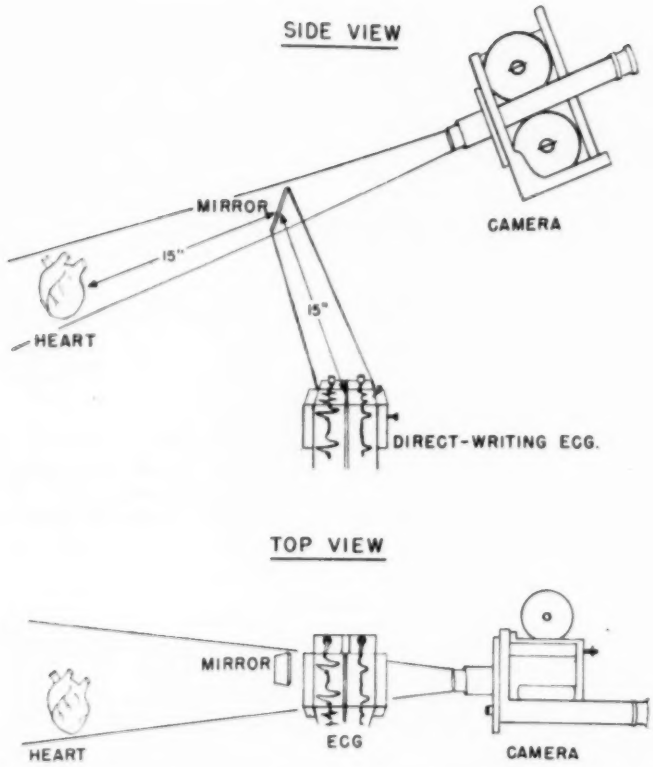

Fig. 1. Diagrammatic representation of the arrangement of equipment used for photographing the heart and electrocardiogram simultaneously. Note that the electrocardiogram is filmed by photographing its reflection in a mirror placed equidistant from the heart and the surface of the electrocardiographic apparatus.

on the heart at such a distance that the part of the heart to be studied fills approximately the left two-thirds of the field. The electrocardiographic machine is placed well below the level of the heart and is mounted on a jack so that adjustments in height are possible. The electrocardiographic machine and a first surface mirror are moved into position so that the reflected image of the trace occupies the right one-third of the field. The mirror image of the electrocardiogram will be in focus only if the distance from the surface of the electrocardiographic machine to the mirror is the same as the distance from the mirror to the heart. The mirror is mounted on a stand with a rack-and-pinion gear for adjusting its height; worm gears with a 100 to 1 ratio control its rotation and angulation. In this way, very fine adjustments in positioning the mirror are possible. Since we photograph the mirror image of the electrocardiogram, an arrangement of the circuits was made which inverts

the actual tracings and thus corrects the maged trace.

Cameras. Two types of cameras were used. A modified Bell & Howell "70" Specialist camera with a speed of 200 frame/sec was employed when visualization of gross movements of the heart was desired. The lenses used with this camera were a 75-mm Pan-Techar, *f*/2.3, and a 100-mm Pan-Techar, *f*/2.3. For extremely detailed analysis the Wollensak Fastax, 16mm camera was used with a 4-in. Wollensak lens, *f*/3.2. The Fastax was used for color pictures taken at 500, 1000 and 2000 frame/sec, and for black-and-white pictures at 5000 frame/sec.

Electrocardiographic Equipment. An ink-writing, dual-channel Brush Magnetic Oscillograph was found to be most suitable for recording the electrocardiogram. This machine has a paper speed of 125 mm/sec which is five times faster than the standard electrocardiographic paper speed. Each complex was thus magnified for great accuracy of analysis. In addition to the two writing pens, a time marker pen was installed at the edge of the paper. A pip every $\frac{1}{5}$ sec produced by a synchronous motor provided the time reference.

Light Sources. In all high-speed photography, the problem of a suitable light source exists. In high-speed medical photography, adequate light must be combined with a minimal amount of heat because one is dealing with living tissue. Excessive heat, of course, is injurious to tissue and precautions must be taken to keep all experiments under at least near-physiologic conditions.

For the Fastax pictures, a bank of from 7 to 20 General Electric 750-R lamps was used on the heart. Usually two or three of these focused on the electrocardiographic paper were sufficient. These lights generate intense heat and various attempts were made to overcome this — heat-absorbing glass, water cells, etc. However, in our setup, these were all awkward and difficult to manage. The simplest solution was to use 50-ft rolls of film in the Fastax camera and to turn on the lights after the camera was started and turn them off (by calculation) just before the film ran through. In this way, perhaps 15–20 ft of film were underexposed but the heart was subjected to the heat for only a very short time — from less than one second to a maximum of three and a half seconds. It was not uncomfortable to hold the hand in the light field for this period of time.

Pictures taken at 200 frame/sec require less light; General Electric RSP-2 lamps were used for this camera speed. A bank of five lamps directed at the heart from a distance of approximately 3 to 4 ft and one lamp on the electrocardiographic paper at about 2 ft were sufficient for good color. The heat problem was obviated by taking continuous film runs of not more than 25 ft at a time. Thus again, the lights were on for only a minimal length of time and the heat to which the heart was exposed was well within the physiologic limit.

For taking pictures of the beating human heart, the precautions and limitations which apply to photography of the experimental animals were even more strict. Thus we have been limited in the number and choice of the patients we have been able to study in this manner. However, a new type of lamp was loaned us recently through the kindness of John H. Waddell of the Wollensak Optical Co. This is the Fastlite, which is a compact unit with a built-in water cell. These lights have proved most satisfactory, for they are less cumbersome than the battery of hot lamps and they give an extremely intense light with a minimum of heat.

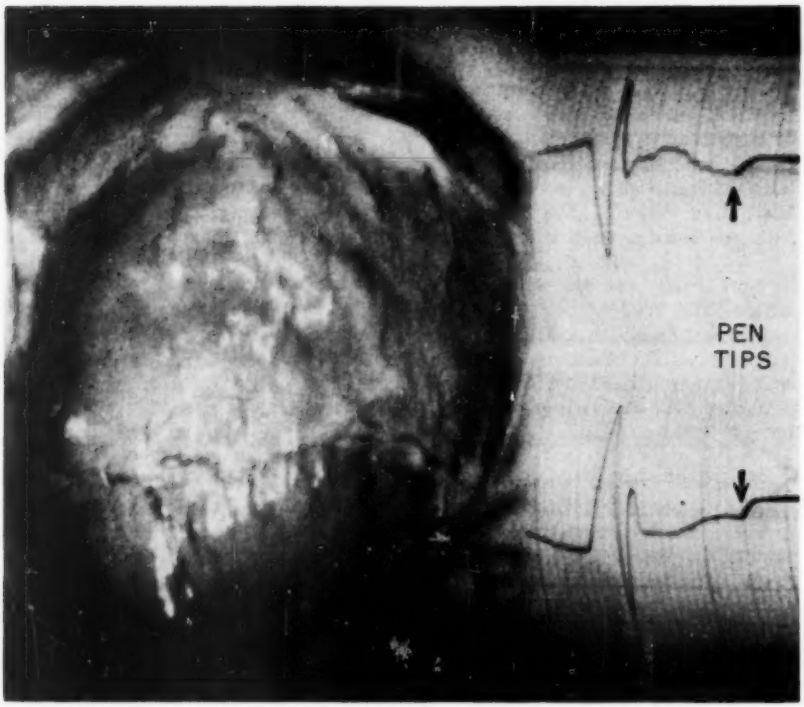

Fig. 2. Enlargement of 16mm frame photographed with the Fastax camera in black-and-white at 5000 frames/sec. The heart is at the left and the electrocardiographic trace is at the right. The ink-writing pens (indicated by arrows) have just finished writing the electrical counterpart of the contraction of the heart from two different leads.

Results and Comment

Figure 2 is an enlarged frame from one of the motion pictures taken by the technique of cine-electrocardiography. The heart is on the left and the mirror image of the electrocardiographic trace is at the right. The pen has just finished writing the electrical complex which corresponds to the contraction of the heart.

The apparatus used for positioning the mirror and the electrocardiographic machine makes it feasible to record photographically any or all parts of the electrical trace, i.e. one channel or two, a narrow strip or a wide one. It is also possible to vary the size and the field of the trace.

The most satisfactory *f* stop for both 200-frame and Fastax pictures up to 2000 frame/sec was found to be 4.5. This gives a fair depth of focus which is necessary since we are dealing with an object which has a field of motion of

about two inches in all directions. Also at this aperture the relatively small amount of light lost is well worth the definition obtained in the pictures. At a camera speed of 5000 frame/sec, the lens is stopped down to $f/8$ using the same amount of light as for the slower speed. In this way almost no loss in definition occurs.

If meticulous care is taken in positioning the heart, mirror and electrocardiographic machine, and careful attention is given to the lighting, exposure and focus, truly beautiful pictures result. More important than esthetic considerations, the films here described now make it possible to demonstrate definite relationships between electrocardiographic patterns and their mechanical counterparts. Although this technique has been in use only a few years, it has already yielded conclusive evidence confirming or disproving a number of previous theories concerning the mechanism of common cardiac disorders. The pictures can be studied repeatedly and thus have proved to be a valuable scientific instrument, for they reveal with fine detail and clarity, action that is not visible to the unaided eye.

Optical Aids for High-Speed Photography

By DAVID C. GILKESON and A. EUGENE TURULA

Several new series of highly corrected lenses for high-speed motion picture and professional 35mm use have been designed with focal lengths ranging from 3.7 mm to 2000 mm. Mirror optics have been used for the longer focal length lenses. Particular optical design and fabrication problems are discussed with reference to mirror optics. Special optical devices to aid the high-speed photographer are discussed.

In order to meet the many needs of professional users of 35mm motion picture cameras, Fastax cameras, 35mm still cameras and specialized applications of these cameras, several new series of lenses and aids have been developed. High-quality optical performance was a primary requirement because the lenses are to be used to record and study a variety of actions and instrument data over a wide field, for tracking, and for photographing and identifying distant objects in detail. The number of elements used in the construction of the lenses ranges from two to eleven (Tables I–V). The number necessary to achieve the performance desired is generally dependent upon the performance, aperture, and coverage requirements. The form and disposition of the elements within the system are dependent upon performance, aperture, coverage, space considerations, and special effects desired. With some exceptions, the number of elements used is no more than necessary and sufficient to meet the performance specifications of the user. The exceptions are the Raptar telephotos (Table II). It was much more important to have as short a back focus as possible for mechanical stability. If the back focus and general adaptability requirements were not important, achromatic doublets or triplets could have been used, depending upon the focal length.

The evaluation of lens performance by photographic resolution measurements has been well covered in previous papers.[4–10] Such a test, however, measures performance of the lens-film combination and the result depends greatly on the methods, techniques and

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Table I. Pro-Raptars

Focal length	f/No.	Diagonal coverage	Type and No. of elements
25 mm	f/2.3	61.2°	6 Gaussian type
35 mm	f/2.3	46.4°	6 " "
50 mm	f/2.3	33.0°	6 " "
75 mm	f/2.3	22.2°	6 " "
101 mm	f/2.3	16.8°	6 " "
152 mm	f/2.7	11.2°	4 Modified Petzval

Table II. Raptar Telephotos

Focal length	f/No.	Diagonal coverage	No. of elements
10 in.	f/4.5	6.8°*	4
12 in.	f/4.5	5.6°*	4
14 in.	f/4.5	4.8°*	4
15 in.	f/4.5	4.4°*	4
16 in.	f/4.5	4.2°*	4
18 in.	f/5.6	3.8°*	4
20 in.	f/5.6	3.4°*	4
24 in.	f/5.6	2.8°*	4

* Lenses marked with asterisk cover more than the angle specified for 35mm single frame with same high-quality performance.

Table III. Mirrotel (Catadioptric Telephotos)

Focal length	f/No.	Diagonal coverage	No. of elements
20 in.	f/5.6	3.4°	3
40 in.	f/8	1.7°	3
80 in.	f/14	0.85°	2

Table IV. Wide-Angle Lenses for 16mm Film

Focal length	f/No.	Diagonal coverage	No. of elements
3.7 mm	f/1.5	142°	8
5.4 mm	f/1.5	84°	8
12.7 mm	f/1.5	56°	11

Table V. Wide-Angle Lenses for 35mm Film

Focal length	f/No.	Diagonal coverage	No. of elements
8.3 mm	f/1.5	142°	8
11.2 mm	f/2.0	84°	8

targets used. Strict control of the variables affecting the measurement is very necessary. Other ways to evaluate lens performance have been discussed also.[11–13] Since the subject is well covered by these authors, no attempt will be made to discuss any of the methods as applied to the lenses which are the subject of this paper other than to state that the "Rayleigh-Conrady" tolerances[14] were used as the basis for the comparison of these lens designs with other similar designs, as well as extensive photographic and optical bench comparisons.

Spherical Mirror Optics (Mirrotels)

Since catadioptric photographic objectives are recent developments in the field it is felt that some discussion of the spherical mirror is necessary.

The advantages of the spherical mirror as an image-forming device have been known for many years. The spherical aberration of a single concave mirror is eight times smaller than that of a single lens of equal aperture and focal length even when the lens has the most favorable bending for minimum spherical aberration.[2] Where high resolution is desired, spherical aberration is objectionable. Therefore, spherical mirrors have been made aspheric by hand correction to minimize the spherical aberration to acceptable limits. To have the advantage of large-aperture spherical mirrors with minimum spherical aberration, Schmidt[1] in 1930

added a corrector plate. Parabolic mirrors with corrector plates have been used. Only recently (Bouwers & Maksutov[2,3]), however, has the spherical aberration of the spherical mirror been corrected by the addition of commercially reproducible all-spherical correctors, thus making available the very real advantages of reflective optics on a wider scale than ever before. Perhaps the most important and most obvious advantage of the spherical mirror is the complete absence of chromatic aberration. If a diaphragm is placed at the center of curvature of a spherical mirror no coma, astigmatism or distortion can occur, for the straight line containing the center of curvature parallel to any given ray of light may be regarded as an axis of the system. There is curvature of field convex to the incident rays, the radius of field curvature being about equal to the focal length for objects at infinity. Field curvature is rarely a problem when the field of view is restricted. Where field coverage relative to focal length is large, suitable field flatteners or curved film may be used.

An inconvenience of the spherical mirror is the reversal in direction of the light rays. There is some loss of light since the object or image receiver intercepts part of the useful beam. The "shadow effect" can be serious with an extensive field of view and small relative aperture. The reversal in path, however, is a real and distinct advantage for long focal length objectives because the "folding" reduces total length to about one-third that of a refractive optical system of equal focal length, thereby giving a more compact and lighter system. Reflective optical systems require different mounting techniques and are much more sensitive to misalignment and spacing changes than refractive optical systems. The correction of spherical aberration is achieved by the addition of a weak spherical corrector lens closely concentric with the primary spherical mirror. With spherical aberration corrected, with coma, astigmatism and distortion eliminated by choice of stop position, and with no chromatic aberrations present, the resolution is primarily limited by diffraction. The spherical mirrors are mounted in a manner to eliminate focus shift caused by temperature variations. Such mounting is imperative by reason of the very sensitive air space between mirror surfaces.

Wide-Angle Lenses

The 84° and 142° wide-angle lenses for 16mm film and 35mm film listed in Tables IV and V have proven to be invaluable where an extreme field of view is required. The systems of the lenses are basically reversed telephotos in form. An extreme depth of field is possible for the lenses even at the maximum $f/1.5$ and $f/2.0$ apertures because of the very short focal lengths and small residual aberrations with the exception of distortion. The resultant distortion is characteristic of extreme wide-angle lenses of high relative aperture. Successful application of the 142° lenses in moderately high-speed motion picture photography is discussed by Bauer and Blake of the Douglas Aircraft Co.[15] The lenses are used to record automatically instantaneous instrument data shown on a wide variety of instruments over a large area where the distance from panel to camera is restricted. In many cases the instrument or objects must be located in azimuth and elevation within the distorted field, necessitating correction charts to compensate for the distortion present in the optical system. The charts are made by photographing an accurately drawn rectangular grid pattern at a predetermined reduction with the lens whose field is to be plotted. The grid spacings are drawn, in both azimuth and elevation, to subtend a given angle in the field of the lens. The photograph obtained is then enlarged with a distortion-corrected lens to a specified

size. The result is finally reproduced in the form of graph paper for locating and recording the data or objects.

The new 12.7 mm $f/1.5$ Cine Raptar for 16mm cameras has been designed to fill the need for a distortion-corrected lens with minimum residual aberrations where extreme coverage is not a primary requirement. It has a diagonal coverage of 56°.

In addition to the basic lenses and lens mountings required, special attention has been given to the varied needs of the users. The most frequent requirements are for compensation of focus shift with temperature changes, and for reticle reference-marking attachment. Normal focus shift with temperature changes may be accomplished by a calibrated air-space change between favorably disposed elements of the system, or by spring-loading the elements of the system against suitably placed invar rods. The method used is determined by the lens design. The correction of focus shift with temperature is most necessary for long focal length lenses.

Many applications of high-speed motion picture photography in the field require a reference mark within the picture area. This is accomplished with an optical reference-marking attachment whose residual aberration contributions to the primary lens must be kept at a minimum. The optical reference-marking attachment is composed of a cross-line engraved field lens and a high-aperture lens which images the cross lines and the image due to the primary objective on the film at 1:1 ratio.

This attachment is par-focussed and can be used with any of the high-speed motion picture camera lenses, and can be adapted easily to other applications.

A means for focussing the lenses is often required and provision is made for focussing the majority of the lenses wherever it is required. There is also some demand for viewing devices through which it is possible to follow the action being photographed. Where required, such devices can be manufactured and supplied. Every attempt has been made to supply to the user in the field a wide variety of lenses, devices and aids to simplify and expedite his work, which is so essential in the common defense effort today.

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A High-Speed Rotating-Mirror Frame Camera

By BERLYN BRIXNER

A high-speed framing camera of some general utility has been developed at the Los Alamos Scientific laboratory and operated up to 3,500,000 frames/sec. Use is made of a rotating mirror and 170 framing lenses working at f/26 to produce frame pictures 1.2 × 1.4 cm in size. Another model operating at 100,000 frames/sec has been made with 90 circular frames 2 cm in size.

THE CONTINUOUS-WRITING high-speed frame camera herein described was made for the detailed study of explosive phenomena and is primarily useful for the photography of high-speed events that are self-luminous or illuminated by very intense explosive light sources using an argon atmosphere.[1] Frame cameras operating up to 500,000 frames/sec have been made,[2,3] but the systems used probably cannot be increased in speed to any great extent because of the limitations of the strength of the rotating mirrors used. The camera to be described was designed for operation up to 3,400,000 frames/sec and makes use of a small mirror so that much higher rotational speeds can be obtained.

Optical System

The principle of operation of the camera is the same as has been used in highest-speed cameras previously made in that an object to be photographed is imaged on the surface of a rotating mirror and then relayed to successive positions on the film by a series of relay lenses. The novel feature of this camera is the use of a small, thin, two-faced rotating mirror and the division of the optical system into two sections so that appreciable blind time is avoided.

Figure 1 shows a schematic isometric view of the optical system. The objective lens L_1 forms an image I_1 in the field lens L_2. The beam-splitting mirror M_1 divides the light from I_1 into two paths A and B. Consider path A first. The combined relay and field lens L_{3A} relays the first image I_1 to the position I_{2A} near the surface of the rotating mirror RM, using the mirrors M_{2A} and M_{3A} to properly direct the light path. The mirror M_{3A} is so placed that the rays forming the image I_{2A} are reflected from the surface of the rotating mirror RM into the final relay lens L_{4A} to form the image I_{3A} in the film plane F_A. A series of lenses identical to L_{4A} are placed in the 180° arc shown to form

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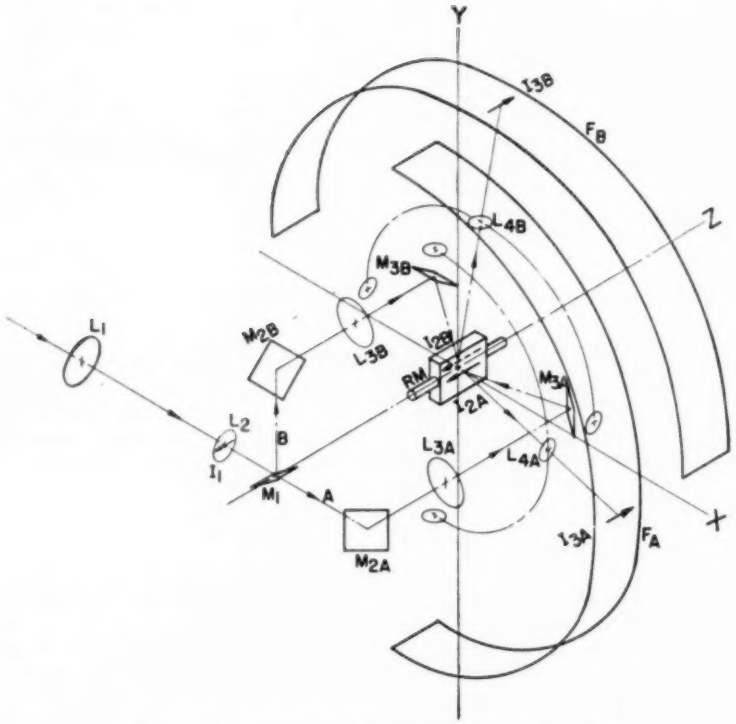

Fig. 1. Optical diagram of high-speed frame camera.

a series of pictures on the film F_A. This lens and film arc records pictures for the rotating mirror in the range of $\pm 45°$ from the position shown. For positions of the rotating mirror beyond that range it is necessary to follow the optical path B which is seen to be at 90° around the Z axis from path A. The combined field and relay lens L_{2B} then relays the image I_1 to the position I_{2B}. The image-forming rays are so directed that they pass into the relay lens L_{4B} to form the image I_{3B} in the film plane F_B. It is thus seen that pictures are obtained for another 90° range of the rotating mirror, adjacent to the previous 90° range, or a total of 180°. Since both faces of the rotating mirror are polished, pictures can be obtained for the entire 360°, with the exception of the region obscured by the mirrors M_{3A} and M_{3B} which amounts to less than 3% of the cycle in a practical case. There are always two images on the rotating-mirror face but the displacement of the relay lens arcs away from the X-Y plane insures that light from only one reaches a relay lens at any one time. Achromatic doublet lenses are used throughout since these give excellent resolution over the small angular field required. The axes of the final relay lenses are coincident with the central optical path and hence the film plane is a conic rather than a cylindric section as shown. The various lenses of the system are assigned focal lengths such that the pupils are located

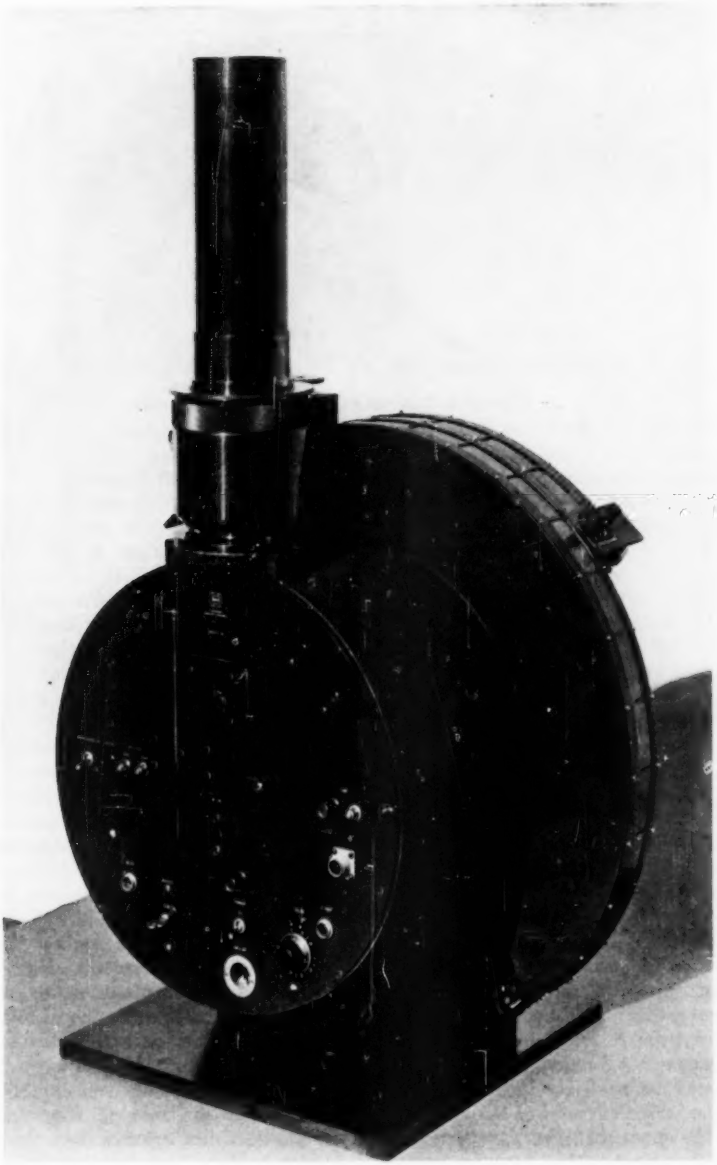

Fig. 2. Exterior view of high-speed frame camera.

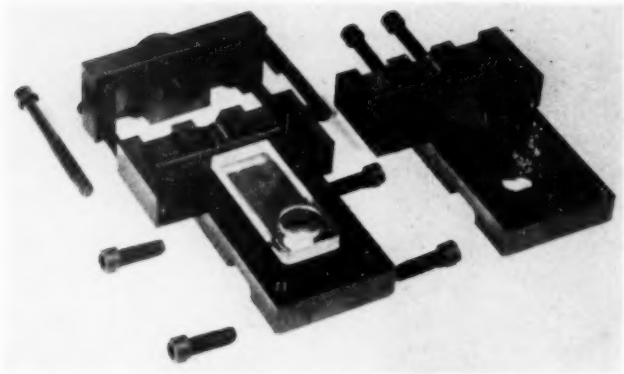

Fig. 3. High-speed shutter used with frame camera.

at the objective lens, the beam splitter, and the final relay lenses. This insures even illumination for all the points of the final image and the minimum exposure time for each picture. To obtain a rate of 3,400,000 frames/sec, a series of 85 framing lenses were used for each of the 180° arcs and the rotating mirror operated at 10,000 rps (revolutions per second).

The loss of light entailed by the use of a beam-splitting mirror may be objectionable to some users even though a factor of 2 or 3 in exposure usually makes only a minor change in the final print quality. In that case the use of a roof mirror in place of the partial reflecting mirror is advisable. The use of a roof mirror also introduces the need for the objective lens to be of twice the aperture and may result in appreciable distortion in the final image. The objective lens axis is then placed midway between the A and B optical paths.

The shutter for the camera is located between the field lens L_2 and the beam splitter, since this part of the system has a small aperture. The shutter must be closed within 1/20,000 sec after the start of exposure or recycling and multiple exposure will occur. Since a mechanical shutter cannot operate in such a short time it was necessary to devise a much faster mechanism. A small block of glass can be rendered sufficiently opaque within a few microseconds by shattering it with a shock wave from a high-explosive detonator. Such an arrangement has been found practical if the glass is enclosed in a suitable steel case.

Camera Construction

The exterior of the camera is shown in Fig. 2. The tube at the top is the focusing mount for the 24-in. objective lens used. The electrical controls for operation of the camera are mounted on the circular end plate. The rectangular projection on the plate is the high-speed explosive shutter mentioned above. It is easily removed for loading with a glass block and the explosive detonator. The viewfinder is located just above the shutter. The adjustable time-delay and detonator firing circuits are housed within the camera body. The two semicircular relay lens rings and film holders are seen at the rear of the camera. Standard 35mm camera cassettes are used to hold the film.

The disassembled explosive shutter is shown in Fig. 3. It is made of steel and withstands the detonator explosion

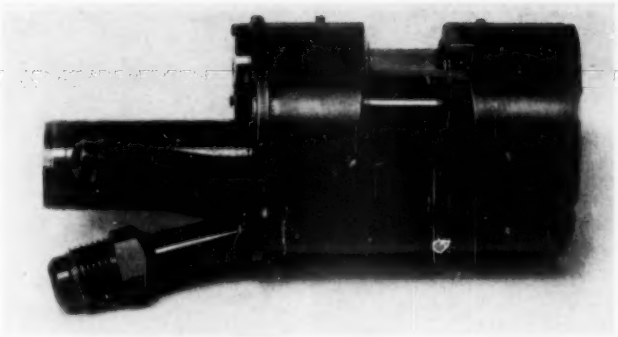

Fig. 4. 10,000-rps turbine with rotating mirror.

without any noticeable deformation of the piece. The $\frac{1}{2}$-in. round optical aperture is near the center of the shutter. Circular pieces of transparent plastic are fitted in these holes to prevent glass fragments from entering the camera. The block of $\frac{1}{2}$-in. plate glass fits in the long groove. The electric detonator (not shown) is pressed against the end of the glass block by means of the hollow screw which fits in the shutter cap. A chamber is formed around the detonator so that the explosive gas pressure will not be too high before exhausting to the outside through the ports in the cap. The detonator is loaded after the shutter has been assembled and fitted to the camera.

The 10,000-rps rotating mirror and air turbine drive[4] is shown in Fig. 4. The mirror has faces $15\frac{1}{2} \times 17\frac{1}{2}$ mm and is 8 mm thick. The air and oil lines for driving and lubricating the unit are at the left. The compact construction was achieved by combining the mirror and turbine into a unit. There is a turbine and sleeve bearing at each end of the mirror. Dural bucket wheels are press-fitted on the mirror shaft. Ordinary No. 10 grade lubricating oil at 100 psi in a circulating system is used for lubricating and cooling of the bearings. The bucket-wheel manifolds are so arranged that the exhaust air sweeps the bearing-oil leakage out the exhaust pipe so that it will not deposit on the mirror and optics inside the camera. A $19 \times 17\frac{1}{2}$ mm drive has also been constructed so that image cutoff is avoided when the mirror is at 45° to the optic axis. This larger size mirror operates with very little strength safety factor at 10,000 rps, and its use is avoided when the highest speed of operation is required.

The camera has an effective aperture of $f/26$ and the final image size is 12×14 mm. Dynamic resolution tests with Shell Burst Panchromatic film give 30 lines/mm over the entire picture area. Diamond shaped stops[5] are used for the lenses as it has been found that there is no practical loss of resolution relative to a circular or rectangular stop of the same linear dimensions. The diamond stop has the advantage that the effective time of exposure is about two-thirds of that obtained by a rectangular stop.

The design of the camera is such that it is adaptable for a wide range of operating speeds. Another model almost identical in appearance to the one illustrated was made for operation at 100,000 frames/sec to give 90 20-mm diameter images. It uses an electric motor drive to give a mirror speed of 550 rps.

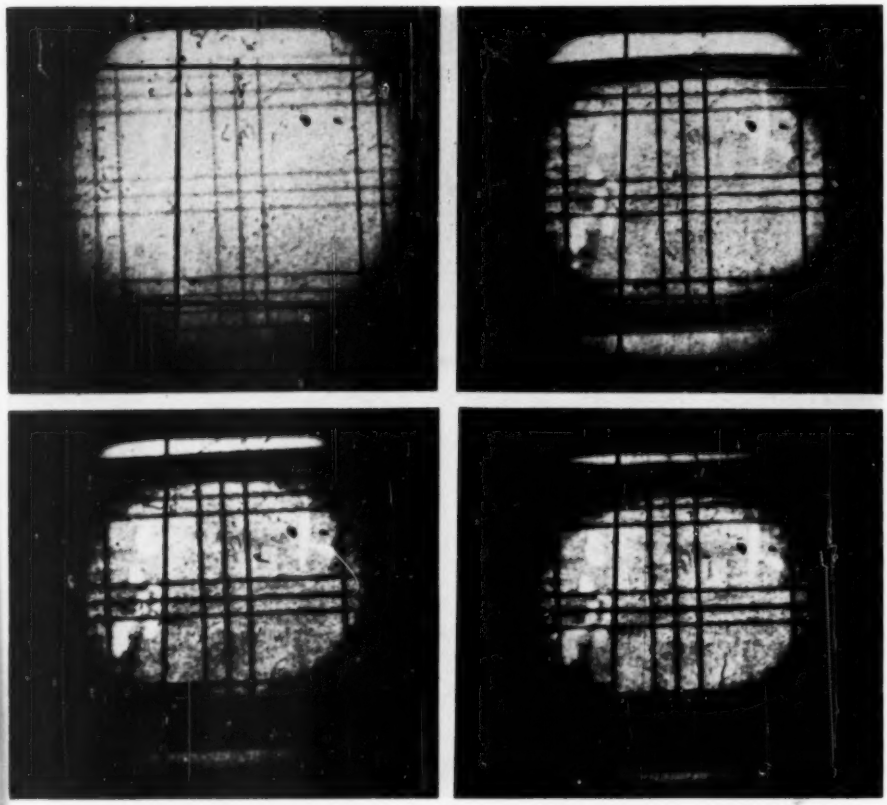

Fig. 5. Photograph of the surface of an explosive-driven metal plate.

Sample Photographs

The photographs in Fig. 5 are a few of the frames from a series showing the surface of an explosive-driven metal plate[6] by reflected light. An explosive flash with an argon atmosphere was used to illuminate the plate and the camera was operating at about 3,500,000 frames/sec. The first frame shows the surface of the plate just before it was struck by a shock from behind. The dark lines are from the reticle in the optical system of the camera. The fine triple-line reticle is painted on the plate. The second frame shows the plate within 0.3 μsec after being struck by the shock. There is a considerable increase in the contrast of the reticle lines and trivial imperfections of the plate surface show up strongly. A velocity of 3,000 m/sec is attained almost immediately and the movement is easily detected on the succeeding frames by examination of the relative positions of the two reticles.

Figure 6 shows a contact print of the sequence of negatives obtained when exploding primacord was photographed in silhouette at 1,700,000 frames/sec. A scale has been placed adjacent to the

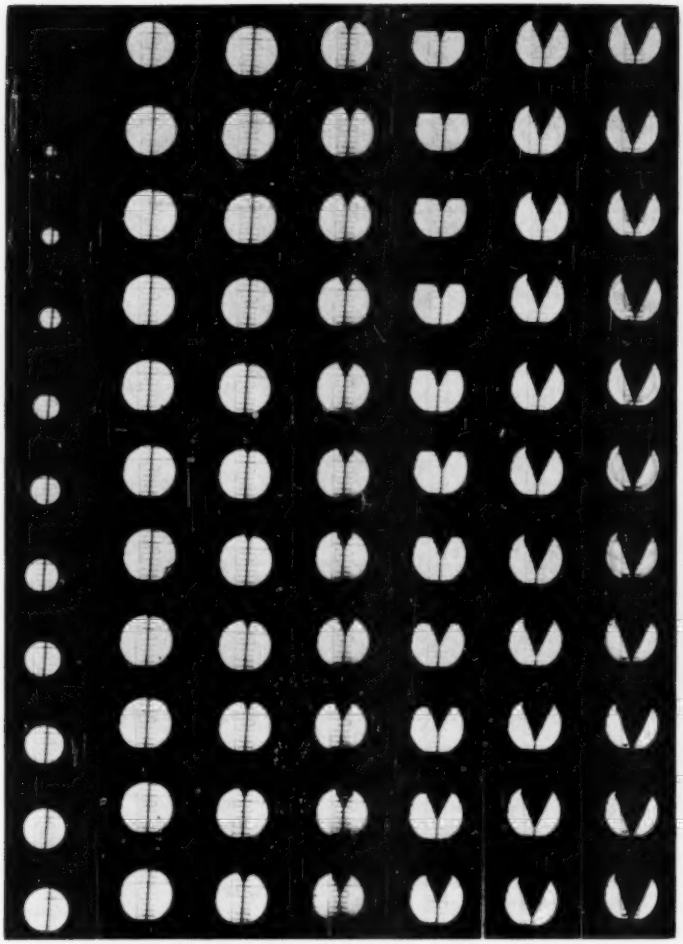

Fig. 6. Contact prints of film showing exploding primacord.

primacord to facilitate measurement, and an explosive light source was used. The early frames show the light source as it brightens up, and shortly thereafter the shock wave from the primacord can be seen to progress across the illuminated area. The shock wave was found to be traveling at 6.2 mm/μsec along the primacord.

Figure 7 shows a 10× enlargement of one of the frames from Fig. 6.

Conclusion

The continuous-writing frame camera described is the fastest practical camera so far produced. Its use is probably largely limited to the study of high-explosive phenomena where the destruc-

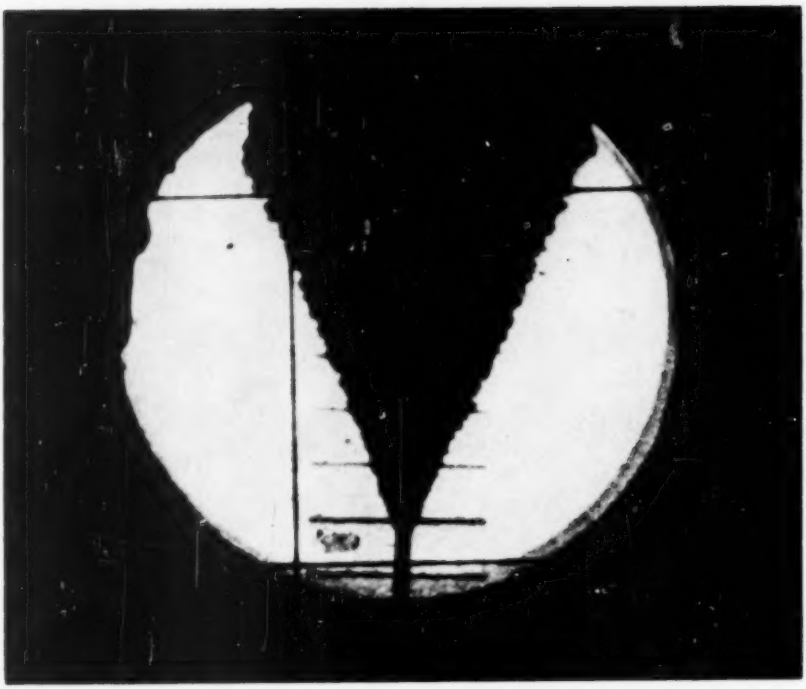

Fig. 7. 10X enlargement of photograph showing exploding primacord.

tion of the object being examined is of no importance. Somewhat slower models of the camera (with even better space resolution) can undoubtedly be used to obtain reflected light photographs of objects illuminated by the high-intensity gas-discharge lamps. The camera is rugged in construction and can be readily moved about. It has been found that the sequence of 50 to 100 frames obtained is quite adequate for the studies so far encountered.

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4. The perfection of this rotating mirror drive is largely due to the efforts of W. E. Buck, Los Alamos Scientific Laboratory of the University of California, Los Alamos, N.M., with considerable assistance by Prof. J. W. Beams, University of Virginia, during the initial development stage.
5. The use of diamond stops was suggested by T. E. Holland, Los Alamos Scientific Laboratory of the University of California, Los Alamos, N.M.
6. W. E. Deal and R. G. Shreffler, "Free surface properties of explosive driven metal plates," Phys. Soc., Salt Lake City, Utah, June 27, 1952.

Discussion

Dave Miller (Chairman of the Session; Battelle Memorial Inst.): I would like to congratulate the author, Berlyn Brixner, on making some progress toward a name for this camera, which it needs rather badly. It has often been called the "Rotating-Mirror Camera." There is a good deal of ambiguity there because the term "Rotating-Mirror Camera" might apply to a camera which simply causes an image to move continuously on a film and might not necessarily refer to this type of camera in which a reflected beam of light rotates about a focused image as a center. I have invented my own name for this type of camera which I shall describe at the next session of this symposium.

Jean St. Thomas (Civil Aeronautics Admin.): How do you eliminate schlieren patterns of the air surrounding the mirror, or does the mirror run in a vacuum?

[*Mr. Buck, who read the paper, replied. The following more tightly knit answer has been supplied by the author.*] Schlieren patterns in air are made visible by means of collimated light beams or an equivalent system using a point light source and a restricting field stop in a suitable optical system. The image on the camera's rotating mirror is formed by $f/32$ beams and these are sufficiently large so that no schlieren patterns are visible. The optical disturbances in the air surrounding the mirror could easily deteriorate the final image resolution were it not for the fact that they occur adjacent to the image on the mirror and hence have only a short optical lever arm with which to operate. If there were trouble of this kind, it could be greatly reduced by using some gas with a high sound velocity for the mirror atmosphere, for example helium or hydrogen. The latter is dangerous to use because of its highly inflammable and explosive nature.

Mr. Miller: I can't recommend rotation in a vacuum as a solution to the problem of these high-speed rotating mirrors. That caused us no end of grief at NACA; because of the absence of air, oil spattered without limit and the very negligible amount of oil that came through the bearing came up onto the rotor and spattered off onto the optics. It presented a problem without any solution. We tried for months every conceivable sort of trap to eliminate this spattered oil, but we were not successful. And because of that fact we had to resort to an electromagnetic suspension and an electromagnetic drive for the rotor, as long as we spun it in the vacuum. With the electromagnetic drive I understand this rotor, weighing two-thirds of a pound, eventually reached a speed of 4,000 rps, corresponding to 800,000 frames a second for that camera.

Acoustic Problems at the "Waldbühne" Open-Air Sound Theater in Berlin

By HANS SIMON

Acoustic problems arising in connection with the reproduction of sound films in an open-air theater are discussed. The proper arrangement of loudspeakers as well as the careful adjustment of their beam direction is of utmost importance. It is demonstrated that a uniform sound level with a considerable increase in volume can thereby be attained. Furthermore, as a result of the concentration of sound waves, a substantial increase in the frequency band will occur. The amplifier power necessary for the required acoustic output is calculated.

THE OPEN-AIR theater known as Waldbühne Berlin, built about twenty-five years ago, has now been arranged for the reproduction of sound films. Figure 1 shows the screen with the loudspeaker installations mounted on both sides. The front row of seats is about 164 ft and the back row 394 ft from the screen. For these viewing distances a 36 × 26 ft screen was used. Reproduction of sound films had to be satisfactory for the entire audience of 25,000 persons. To meet this requirement it was essential to achieve adequate synchronization of picture and sound and uniform sound level in all parts of the arena.

Synchronization

It is obvious that acoustic quality in an open-air theater is dependent on very different conditions from those in a closed room. In an open-air theater all the effects due to reverberation are absent and only the laws for linear and unrestricted diffusion of sound waves need be considered. Their velocity of diffusion, however, will be of particular importance. The long distances sound must travel in an open-air theater tend to produce an undesirable effect on the audience due to the time-lag between picture and sound. Consequently, scenes of rhythmic movement such as a dance would deviate from the rhythm of the accompanying music. Similarly, it would be especially disturbing if the sound produced by a singer were not synchronized with lip movements. It is therefore of the first importance that the phase difference between picture and sound be reduced to a minimum. The solution which proved successful for the Waldbühne Berlin is described as follows.

As far as is now known, the following

A contribution submitted on September 23, 1952, by Hans Simon, 6 Xantener Str., Berlin W. 15, Germany.

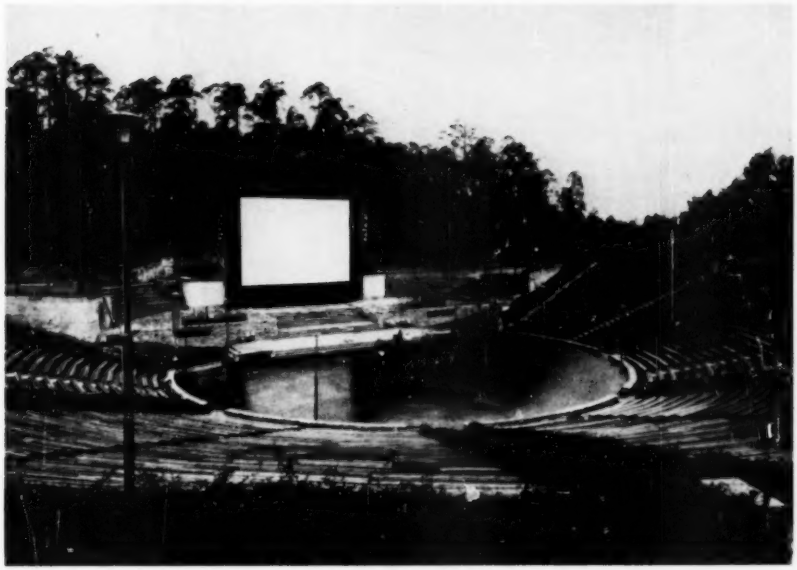

Fig. 1. The Waldbühne Berlin Open-Air Sound Theater

method is the only one that can be used satisfactorily to reproduce sound films for large audiences. The method used takes advantage of the ability of human eyes and ears to perceive optical and acoustic phenomena belonging together as synchronous when the time-lag between them is not too great. According to experience the time-lag must not exceed 0.1 sec*; whether the picture or the sound precedes is unimportant. Therefore, if at A (Fig. 2) there is perfect synchronization, then virtual synchronization will occur for all viewers seated within a range of 112 ft (i.e. 0.1 sec) each side of A. Hence the radius of virtual synchronization is 224 ft. Since the value of 0.1 sec may not be exceeded for the reasons stated above, the synchronization area of 224 ft must be taken as the limit beyond which no satisfactory reproduction of sound films is possible. *Therefore, the use of an open-air theater for sound will always be limited to a linear distance of 112 ft either side of the calculated line of synchronization.* Satisfactory vision in this area is dependent solely on the size and illumination of the screen and, therefore, on the light output of the projector.

The vertical section of Waldbühne Berlin (Fig. 2) shows that the distance of A from the screen corresponds to 0.25 sec (sound path = 276 ft). To obtain synchronization at A the sound produced by the loudspeaker must precede the picture by 0.25 sec. This may be accomplished by using a special copy of the film or by altering the length of the film loop between the film gate and the sound head of the projector. Since this is a problem of construction it will not be discussed further.

In actual practice, this method of preceding picture by sound produced

* The normal limit used in synchronization practice.

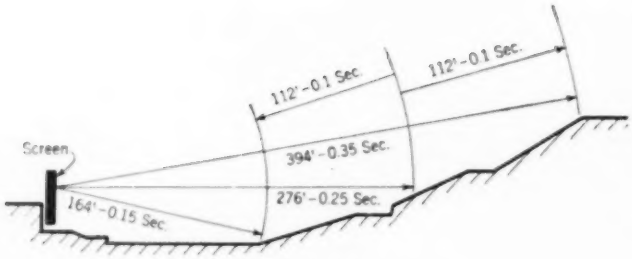

Figure 2.

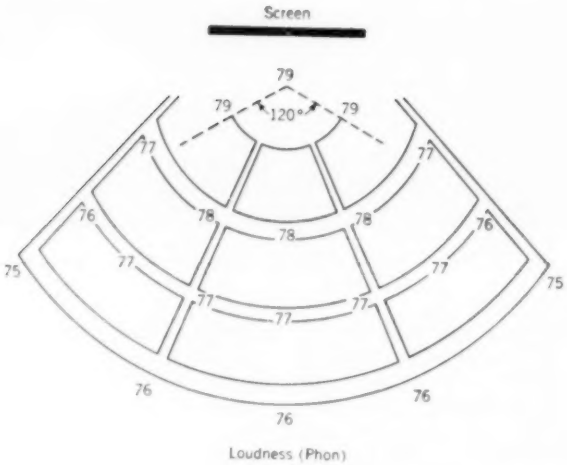

Figure 3.

acceptable synchronization throughout the 224-ft area.

Uniform Sound Level

Uniform sound level for all parts of the arena was obtained by appropriate distribution of the loudspeaker units and by carefully adjusting their beam direction. Each of the loudspeaker units consisted of two groups of three speakers of different frequency characteristics. Numerous tests showed that the most suitable arrangement was obtained with the loudspeaker units placed on both sides of the screen (Fig. 1) at about two-thirds of its height.* A great many tests and measurements were necessary to obtain the correct adjustment of the sound direction for all the loudspeaker units. The final result of the measurement of the sound levels may be seen in Fig. 3. With an average

* This distance was determined by the structure of the Waldb¨hne Berlin and must not be assumed to be generally acceptable.

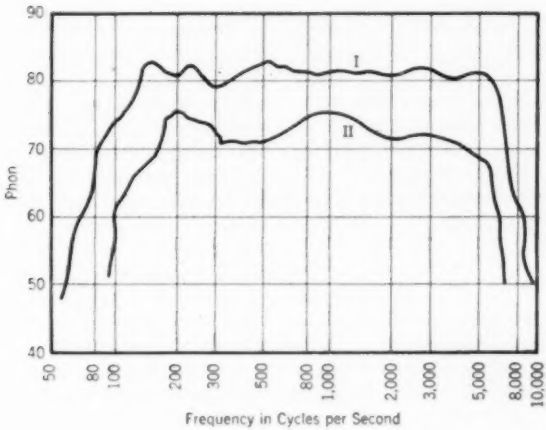

Figure 4.

sound level of 77 phons† the deviations were nowhere more than 3 phons. The final arrangement of the loudspeaker units and their adjustment resulted in a considerable improvement of the sound level through the frequency range. This result, based on theoretical calculation, is produced by the effect of concentration due to the adjustment of the loudspeaker units.

A comparison of the loudspeaker arrangement described above with that of an arrangement located at one-quarter of the screen height without special adjustment of the loudspeaker direction may be of interest. Figure 4 shows the frequency characteristics taken at a distance of 262 ft from the loudspeaker units. Curve II refers to the loudspeaker arrangement at one-quarter the screen height while Curve I refers to the final arrangement. The data for both curves were obtained with the loudspeakers equally powered (50 v), corresponding to an amplification power of about 40 w. Comparison of the two curves shows an increase in the sound level of about 8 phons within the range of 100–8000 cycles/sec. Concentration of the sound waves produced considerable improvement in acoustic efficiency and eliminated overloading at high sound levels, i.e. distortion.

In addition, it is evident from the two curves that a notable enlargement of the frequency band in both high and low ranges has occurred. If J_I and J_{II} be the amount of energy of sound at loudspeaker units I and II, the following equations apply:

$$10 \log \frac{J_I}{J_0} = a$$

$$10 \log \frac{J_{II}}{J_0} = a + 8$$

where J_0 is the sound energy at threshold. Subtracting the first equation from the second:

$$10 \log \frac{J_{II}}{J_0} - 10 \log \frac{J_I}{J_0} = 8$$

or

$$10 \log \frac{J_{II}}{J_I} = 8$$

$$\log \frac{J_{II}}{J_I} = .8$$

$$\frac{J_{II}}{J_I} = 6.3$$

† The loudness level, in phons, of a sound is numerically equal to the sound pressure level in decibels, relative to 0.0002 microbar, of a simple tone of frequency 1000 cycles/sec which is judged by the listeners to be equivalent in loudness.

These sound measurements were made using continuous tones. The significance of such an increase in the sound level (8 phons) becomes apparent when it is realized that this corresponds to an actual power ratio of 6.3 times. In other words, proper orientation and placement of the speakers resulted in an improvement in acoustic efficiency by a factor of 6.3.

Amplifier Power

Finally, the amplifier installed at the Waldbühne Berlin may be described. It was considered desirable to create a sound level of 70–75 phons at the back of the theater. Since it is known that with each 325 ft of sound path loss of sound energy is 5–7 phons, the acoustic power required was calculated to be 8–10 acoustic w. To produce this with the loudspeakers used called for an amplifier power of about 120 electrical w. A potential 150-w unit was installed to satisfy special conditions such as the attenuation of sound waves occurring with changes of temperature.

According to the judgment of experts the technical problems arising from the use of the Waldbühne Berlin as an open-air theater for sound reproduction have been solved quite satisfactorily.

Errata

Raymond Spottiswoode, N. L. Spottiswoode and Charles Smith, "Basic principles of the three-dimensional film," *Jour. SMPTE, 59:* 249–286, Oct. 1952.

Page 254, column 2, footnote, last line:
For: 1 metric $\rho = 10{,}000/\text{distance in cm}$.
read: Distance in metric $\rho = 10{,}000/\text{distance in cm}$.

Page 256: Fig. 2b title, next to last line:
For: When $t_s > t_c$, $l - r' > l - r$
read: When $t_s' > t_c$, $l - r' > l - r$

Page 271, column 2: The equation numbered 11 should be numbered 18.

Some Geometrical Conditions for Depth Effect in Motion Pictures

By EUGENE MILLET

The fundamental considerations affecting stereoscopic vision are used as a basis of a description of the Kern-Paillard Bolex stereo system for 16mm film.

THE PERCEPTION of a stereoscopic image is a complex phenomenon; the process of synthesis whereby one forms an accurate idea of an object observed in all its dimensions from the elementary data of the senses involves both psychology and cerebral physiology.

It is obvious that, for purposes of artificially producing the impression of depth by means of plane images, only the sensory aspect of the problem need be considered; the illusion would be complete if all the sensations present upon observation of the object in nature could be produced artificially at the same intensity as in natural vision.

The purely optical sensations due to the two retinal images depend on conditions of definition, accommodation, coloration, distribution of light and shade, perspective, and movement of the object. In addition, the state of convergence of the eyes produces certain muscular sensations which play an important part in effortless depth vision.

A contribution submitted October 14, 1952, by Eugene Millet, Development Dept., Paillard S.A., Yverdon, Switzerland; and Paillard Products, Inc., 265 Madison Ave., New York 16, N.Y.

When an object located at a finite distance in nature is observed with the naked eye, the axes of the two eyes converge upon a certain point on the object, and its various elements are seen at unlike angles by the left eye and the right. In a stereoscopic cinematographic projection, the spectator views two images on a screen, whose dimensions are generally different from those of the object originally photographed; moreover, the angle at which each eye sees the object depends on certain of the technical conditions under which the shot was taken. We shall inquire, by a simple geometrical approach, what conditions must be satisfied in order that the spectator will see the projected image at the same angles at which he might have seen the object in nature.

Conditions for Natural Relief

We define "natural relief" in the following way:

Let there be an object A occupying a certain space in nature. Having photographed this object, we view a pair of images A' on a projection screen. We speak of *natural relief* if all the dimensions of A' are seen by each of the spectator's eyes at angles equal to those at which

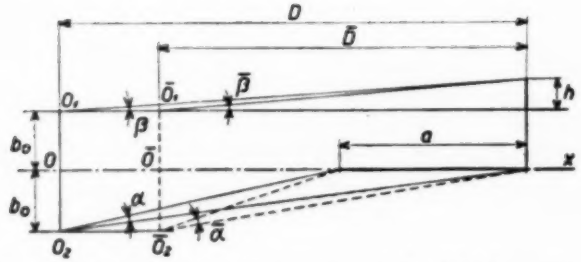

Fig. 1. Relationship between transverse and axial enlargement.

each eye respectively would see all the dimensions of A in nature when stationed at the desired distance from A.

First let us recall the relationship subsisting between transverse enlargement and axial enlargement in direct vision of an object in nature (Fig. 1).

Let Ox be the ocular axis, and let h be a transverse object element and a an object element along Ox. The elements h and a are assumed small relative to the distance D. Designating the ocular base by $2b_o$, we have

$$\beta = h/D; \tag{1}$$

$$\alpha = ab_o/D(D - a). \tag{2}$$

If the observer stations himself at a point $\bar{O}$, we have

$$\bar{\beta} = h/\bar{D}; \tag{1}$$

$$\bar{\alpha} = ab_o/\bar{D}(\bar{D} - a). \tag{2}$$

Upon displacement of the observer from O to $\bar{O}$, h undergoes an apparent transverse percentage enlargement of

$$E_t = \bar{\beta}/\beta = D/\bar{D}, \tag{3}$$

and a an apparent axial percentage enlargement of

$$E_a = \bar{\alpha}/\alpha = D(D - a)/\bar{D}(\bar{D} - a). \tag{4}$$

Replacing $\bar{D}$ in (4) by its value from (3), we have

$$E_a = E_t \frac{D - a}{D/E_t - a}. \tag{5}$$

The viewing of an object in nature is thus subject to two simple rules (3) and (5).

To the naked eye, the only way to vary the apparent dimensions of an object is to approach it or withdraw from it; if, in the course of such a relocation of the observer, the angles at which he sees the transverse dimensions of the object have varied in a proportion E_t, the angles at which he sees an axial element a will have varied in a proportion E_a dependent upon E_t by the relation (5).

To determine what conditions must be met by a stereoscopic projection in order for the spectator to see any image whatsoever in natural relief (in the sense of our definition), we shall proceed as follows:

A spectator stationed at a distance D' from the projection screen sees a transverse element h'' of the image A' at an angle β'. We first inquire at what distance D from the object A one would have to be stationed in nature in order to see the transverse element h at an angle $\beta = \beta'$. From this distance D, we should see the axial element a at an angle α, and we must find under what conditions the spectator at distance D' from the screen will see the image of a at an angle $\alpha' = \alpha$. The latter equality must hold regardless of the value of a.

Let a photographic lens of focal length f_v be placed at a distance X_v from the object photographed; on the film, it projects an image h' of h such that

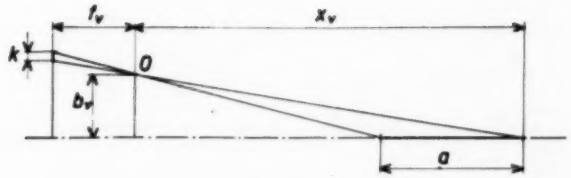

Figure 2.

$$h' = hf_v/X_v. \tag{6}$$

If a projection lens of focal length f_p projects this image h' on a screen placed at a distance X_p, the image h'' on the screen will have the dimension

$$h'' = h'X_p/f_p = hf_vX_p/f_pX_v. \tag{7}$$

A spectator stationed at a distance D' from the screen sees h'' at an angle β'

$$\beta' = h''/D = hf_vX_p/f_pX_v \cdot 1/D'. \tag{8}$$

The distance D at which one must be stationed to see h at the angle $\beta = \beta'$ in nature is given by

$$h/D = hf_vX_p/f_pX_v \cdot 1/D',$$

or

$$D = f_pX_v/f_vX_p \cdot D'. \tag{9}$$

Consider a shot of the axial element a with a semibase b_v (Fig. 2).

$$k = af_vb_v/X_v(X_v - a). \tag{10}$$

Upon projection, we obtain an image k' of k on the screen:

$$k' = kX_p/f_p,$$

hence

$$k' = af_vb_v/X_v(X_v - a) \cdot X_p/f_p. \tag{11}$$

The spectator sees k' at an angle α'

$$\alpha' = k'/D' = f_vX_p/f_pX_v \cdot 1/D' \cdot ab_v/(X_v - a). \tag{12}$$

We are to have $\alpha' = \alpha$, or

$$f_vX_p/f_pX_v \cdot 1/D' \cdot ab_v/(X_v - a) = ab_o/D(D - a). \tag{13}$$

The value of D is given by (9). Introducing this value of D into (13), we have

$$b_o/b_v = \frac{D'f_pX_v/f_vX_p - a}{X_v - a}. \tag{14}$$

The condition (14) must be satisfied for any value of a whatsoever, and the ratio b_o/b_v cannot vary with a. It is therefore necessary that $\partial(b_o/b_v)/\partial a = 0$ no matter what a is, or that

$$X_v = D'f_pX_v/f_vX_p = 0. \tag{15}$$

This relation (15) determines the value of D'

$$D' = X_pf_v/f_p. \tag{16}$$

Substituting this value of D' in (14),

$$b_o/b_v = 1, \quad b_o = b_v; \tag{17}$$

in (9), $$D = X_v; \tag{18}$$

in (8), $$\beta' = h/X_v; \tag{19}$$

and in (12) $$\alpha' = ab_v/X_v(X_v - a). \tag{20}$$

To summarize, the spectator receives the illusion of natural relief if the following two conditions are satisfied:

1. The camera base must be equal to the ocular base (relation 17);

2. The spectator must be stationed along the axis of projection at a distance from the screen which is to the projector-screen distance as the focal length of the camera lens is to the focal length of the projection lens (relation 16).

Relations (18), (19) and (20) show us that when conditions 1 and 2 above are satisfied, the spectator will see all the dimensions of the image at the same angles as the photographer saw the corresponding dimensions of the object while shooting.

Condition 1 is readily satisfied by construction; the camera must have a base between 63 and 67mm.

As for condition 2, it is to be noted

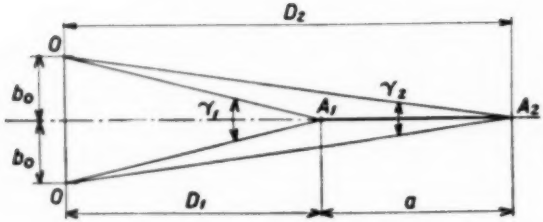

Fig. 3. Convergence and stereoscopic depth of field.

that this condition cannot be satisfied strictly for any spectator; for it is impossible to have the spectator's head on the axis of projection without casting a shadow on the screen. Still, it must be remembered that the closer the spectator is to the axis, the more closely the observed depth effect will approach natural relief. Again, if the spectator is not stationed at the distance D' from the screen as defined by (16), he will see a somewhat distorted relief. In particular, if the spectator is farther from the screen the image of an axial element a, or the segment transversely projected into k', will suffer an apparent enlargement E_a' equal to the apparent enlargement E_t' suffered by the image h'' of h. Upon projection, therefore, we have $E_a' = E_t' - 1$. In nature, if the observer had withdrawn from the object so that the transverse dimensions would suffer an enlargement $E_t = E_t'$, the axial element would have suffered an apparent enlargement

$$E_a = E_t' \frac{D - a}{D/E_t' - a},$$

given by (5). Comparing E_a and E_a',

$$E_a/E_a' = \frac{D - a}{D/E_t' - a}.$$

Having assumed $E_t' - 1$, we have $D/E_t' - D$ and

$$E_a/E_a' - 1 \quad \text{or} \quad E_a' - E_a.$$

We can therefore conclude that if the spectator is farther from the screen, the depth of objects will be exaggerated, while if he is closer to the screen, the picture flattens.

The choice of focal lengths of cameras and projectors must be such that the largest possible number of spectators can be placed near the position of natural relief; this position should not be too close to the screen, since the spectators at optimum distance would then necessarily be fairly far away from the projector-screen axis.

Stereoscopic Depth of Field

Comfortable stereoscopic vision is impossible unless the extreme frontal planes of the object lie within two definite limits.

Let A_1 and A_2 be the intersections of the two extreme frontal planes of the object with the ocular axis of the eyes O, semibase b_o. The convergence is $\gamma_1 = 2b_o/D_1$ at A_1 and $\gamma_2 = 2b_o/D_2$ at A_2 (Fig. 3). For comfortable observation of the object, it is necessary that the maximum increment of convergence of visual rays, i.e. the difference $\gamma_1 - \gamma_2$, should not exceed a certain limiting value. This limiting value, unfortunately, varies from one observer to another; some people find a convergence differential of as little as 1° slightly troublesome, while others tolerate much higher differentials without fatigue. Since a stereoscopic film is to be viewed by numerous spectators, we must adopt a maximum value of $\gamma_1 - \gamma_2$ sufficiently small so that anyone may witness the performance without fatigue. At the same time, the limit must not be too

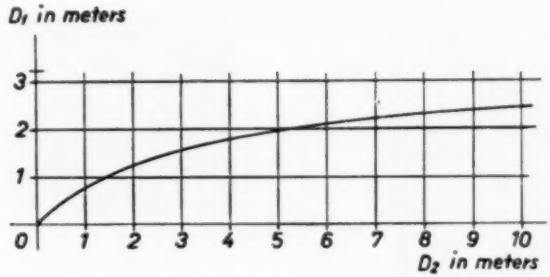

Fig. 4. Corresponding values of D_1 and D_2 for determining stereo depth of field.

low, so that photographic possibilities will not be excessively restricted. As the maximum convergence differential, we therefore take $\gamma_1 - \gamma_2 = 70'$; this value, which seems reasonable for practical purposes, is in accordance with the stereoscopic projection German Standard DIN 4531 (July 1949, Beuth-Vertrieb GmbH, Berlin W15 and Köln).

In the case of cinematographic equipment, when the camera base is equal to the ocular base, the convergence differential is the same for the spectator viewing the image a' at a distance $D' = X_p f_o / f_p$ from the screen and for the photographer viewing a in nature while shooting.

We may therefore say that D_1 and D_2 are the distances from the camera to the boundaries A_1 and A_2 of the subject, within which the photographer can shoot without exceeding a visual convergence of $\gamma_1 - \gamma_2$ for the spectator at distance D' from the screen.

We have

$$\gamma_1 - \gamma_2 = 2b_o(1/D_1 - 1/D_2), \qquad 1/D_1 - 1/D_2 = (\gamma_1 - \gamma_2)/2b_o. \tag{21}$$

If $\gamma_1 - \gamma_2 = 70' = 0.02$ radians and $2b_o = 64$mm,

we have $1/D_1 - 1/D_2 = 0.3125$ (21)

when D_1 and D_2 are expressed in meters (Fig. 4).

For example, if we are to photograph a subject whose most distant part is at $D_2 = 5$ m from the camera, the relation (21) shows us that no part of the scene photographed should then be less than $D_1 = 1.95$ m from the camera.

This limit on convergence differential therefore determines a maximum picture depth as a function of the range—a depth of field, called the stereoscopic depth of field.

Stereoscopic Depth of Field and Position of Projector Windows

In a stereoscopic projection, the field of the image projected is bounded laterally and vertically by the projector windows. The two projector windows form a stereoscopic pair, and depending on the lateral position of the windows with respect to the centers of the images photographed, the resultant image will be more or less distant from the spectator. For example, if the windows were centered with respect to the images of the points at infinity, along the axes of the camera lenses, the picture would seem to be located at infinity; with such a set-up we would always have $D_2 = \infty$, and no object could be photographed at less than $D_1 = 3.2$ m from the camera, otherwise the picture image would project beyond the stereoscopic depth of field.

Thus it turns out to be desirable to make the set-up such that the stereoscopic image of the projection windows seems to be an object located at 3.2 m from the camera. The frame then looks like

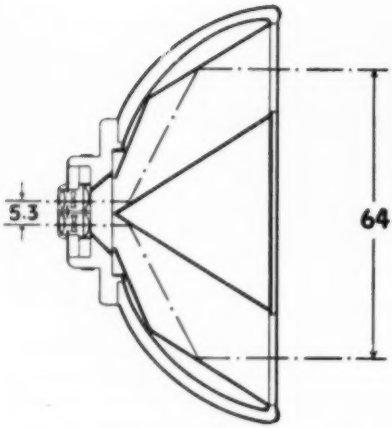

Fig. 5. Schematic diagram showing the path of rays through both openings at 64 mm, through prisms to the Yvar lenses, then on to 16mm film.

a window through which the spectator sees everything that has been photographed between 3.2 m and infinity.

Objects closer to the camera than this may be photographed. If the most distant plane of the subject is 3.2 m from the camera ($D_2 = 3.2$), objects as close as 1.6 m ($D_1 = 1.6$) may be filmed. The image will then seem to be between the window and the spectator, and precautions should be taken while photographing so that features situated in front of the window will not seem to be cut off by its edges.

In order to photograph at distances of less than 1.6 m, it would be necessary to change the position of the frame in order for the entire view to lie within the stereoscopic depth of field.

The Kern-Paillard Instrument

The photographic instrument has been built as an accessory for the H16 De Luxe Paillard Camera. It is a compact assembly screwed to the turret in place of an ordinary lens; it is automatically centered with respect to the axis of

Fig. 6. Left- and right-eye Stereo images on standard 16mm movie film.

rotation of the turret, to prevent differences in height between the left-hand and right-hand images. The instrument comprises two Yvar lenses, $f = 12.5$mm, aperture 1/2.8, with parallel optical axes 5.3mm apart. The normal base of 64 mm is obtained by a system of prisms placed in front of the lenses (see Fig. 5).

The two homologous images are located side by side on the 16mm film, and together occupy one 16mm frame (see Fig. 6).

The lenses are universally focused and adjusted to their hyperfocal distance. If we assume a circle of diffusion of 1/50 mm on the film, the depth of field of definition is $\delta = 2.8/50 = 0.056$mm on the print. The hyperfocal distance is therefore

$$X = f^2/\delta = 156.25/0.056 = 2790\text{mm},$$

or 2.8 m. The lenses being adjusted for 2.8 m, good definition can be obtained from 1.4 m to infinity at full aperture. Now we have seen that the stereoscopic depth of field permits us to photograph from 1.6 m to infinity. The universal-focus lens adjusted to hyperfocal distance is thus adequate for all cases.

The projection instrument takes the place of the lens of a standard 16mm projector. It comprises 2 Petzval lenses, $f = 20$ mm, aperture 1/1.6, whose optical axes are parallel and 5.6 mm apart (Fig. 7); the projection windows are centered with respect to these axes. In front of each of these two lenses, there is a polarizer; the planes of polarization of

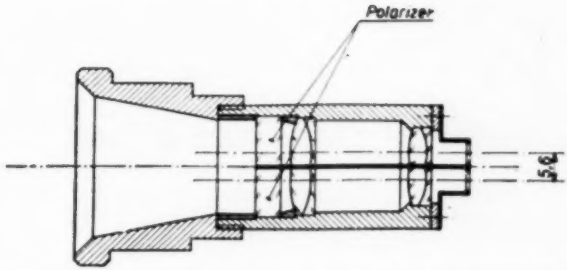

Fig. 7. Schematic drawing of projection lens, showing f:1.6 lenses of Petzval type and polarizing filters. The optical axes are separated by 5.6 mm.

the two polarizers are oriented at right angles and at 45° to the horizontal so that the film can be viewed with polarizing spectacles available on the market, for example Polaroid 3-D Picture Viewer. The projection screen must preserve the polarization of light. A metallized screen coated with an aluminum-base varnish is satisfactory.

We saw, in our discussion of stereoscopic depth of field, that the projection window should be located in space near a plane 3.2 m from the camera. Suppose we are photographing a point A at 3 m from the camera with camera lenses 5.3 mm apart, focal length 12.5 mm, base 64 mm. The two homologous images A' of A on the film will be

$$(64/3000)12.5 - 5.3 = 5.57$$

apart. The two projection windows should therefore be 5.57 mm or about 5.6 mm, between centers, in order for the plane of their stereoscopic image to appear to merge with the plane of A. The optical axes of the two projection lenses are likewise 5.6 mm apart. Under these circumstances, the planes at 3 m from the camera will coincide on the screen within 5.6 mm, regardless of the distance from the projector to the screen; it would be possible to eliminate the projection windows and bound the picture with the edges of the screen itself.

The choice of focal lengths of the camera and projector lenses places the spectator at a distance of

$$D' = (12.5/20).X_p = 0.625.X_p$$

from the screen, or about two-thirds the screen-projector distance, for correct vision of the image.

Thus the Kern-Paillard instrument is a standard-base instrument in which judicious choice of focal lengths of camera and projector lenses affords vision approximating that of natural relief to a maximum number of spectators. The distances between the lenses are such that the image may be bounded either by means of the edges of the screen or by masking the projection lenses; in either case, the stereoscopic image appears to be bounded by a window about 3 m from the spectator. Anything photographed between 3 m and infinity appears behind this window; anything photographed between 1.5 m and 3 m appears between the window and the spectator. Photographing subjects closer than 1.5 m will result in emergence from the stereoscopic depth of field, and is inadvisable without the use of accessories which modify the convergence of axes and focusing of the Kern-Paillard system as they have been described in this article.

Screen Brightness Committee Report

By W. W. LOZIER, Committee Chairman

THE LAST REPORT of the Screen Brightness Committee presented at the April 1950 meeting of the Society[1] related a number of items receiving the attention of the committee. This report will summarize our progress to date and will outline some of our future plans.

1. Subcommittee on Meters and Methods of Measurement: This group under the chairmanship of F. J. Kolb, Jr., has made a thorough study of the measurement of screen brightness and related factors. Specifications have been set up on the range of the variables which will need to be covered by various types of instruments. The report by this Subcommittee has been accepted by the Screen Brightness Committee and recommended for early publication in the *Journal*.

2. Subcommittee on Projection Screens: This group under the chairmanship of Leonard Satz is engaged in the preparation of standards covering the brightness and whiteness characteristics of motion picture screens. The old War Standards of 1945 are being used as a basis of departure.

3. Subcommittee on Illumination Practices: This is a new group recently set up under the chairmanship of A. J. Hatch, Jr., for the purpose of establishing recommended practices concerning distribution of illumination on the motion picture screens.

Theater Survey of Screen Brightness: The Committee has completed a survey of screen brightness and related information in 125 indoor theaters widely distributed over the United States and in 18 West Coast studio review rooms used for viewing 35mm motion pictures. These data have been reported at the two 1951 meetings of the Society,[2,3] and have been published in the *Journal*. This survey has given us a good summary of screen illumination practices in a representative cross-section of the theaters in this country. This information is being used in our further activities looking toward improvement of theater screen illumination.

The Committee hopes to survey a number of representative outdoor theaters during 1953 to obtain information on screen illumination practices in these installations.

Revision of Screen Brightness Standard: The currently applicable American Standard on Screen Brightness, Z22.39-1944, has been modified[4] to include only indoor theaters and therefore exempts outdoor theaters from the provisions of this Standard. The revised standard has been recommended to the ASA for adoption as an American Standard.

Presented on October 9, 1952, at the Society's Convention at Washington, D.C., by W. W. Lozier, National Carbon Company, Division of Union Carbide and Carbon Corp., Fostoria, Ohio.

Preferred Conditions for Viewing Motion Pictures: Our Committee has concerned itself with the fundamental problem of determination and exposition of the preferred conditions for viewing motion pictures. The Committee has encouraged discussion of the history and important factors having technical bearing on this problem. A summary of these matters was published last year in the *Journal* by one of our committee members.[5]

The Committee arranged and sponsored a Symposium on Screen Viewing Factors at the Spring 1951 Convention of the Society. The papers presented at the symposium were published in the September 1951 *Journal*[6] and contain much information pertinent to the determination of preferred viewing conditions. There are indications that our efforts are bearing fruit and that new interest has been stimulated in the experimental determination of some of these factors and further important revelations can be expected.

References

1. W. W. Lozier, Chairman, "Screen Brightness Committee Report," *Jour. SMPTE, 54:* 756–757, June 1950.
2. W. W. Lozier, Chairman, "Report on Screen Brightness Committee Theater Survey," *Jour. SMPTE, 57:* 238–246, Sept. 1951.
3. W. W. Lozier, Chairman, "Further Report on Screen Brightness Committee Theater Survey," *Jour. SMPTE, 57:* 11–15, Nov. 1951.
4. "Revision of Screen Brightness Standard," *Jour. SMPTE, 58:* 452, May 1952.
5. F. J. Kolb, Jr., "The scientific basis for establishing brightness of motion picture screens," *Jour. SMPTE, 56:* 433–442, April 1951.
6. Symposium on Screen Viewing Factors (6 papers), *Jour. SMPTE, 57:* 185–237, Sept. 1951.

The Committee

W. W. Lozier, *Chairman*

H. J. Benham	O. W. Richards
F. E. Carlson	Leonard Satz
M. H. Chamberlin	Ben Schlanger
E. R. Geib	Allen Stimson
L. D. Grignon	C. R. Underhill
A. J. Hatch	G. H. Walter
L. B. Isaac	H. E. White
W. F. Kelley	A. T. Williams
F. J. Kolb	D. L. Williams
L. J. Patton	

Reaffirmation — PH22.50-1952 16mm Projector Reel Spindles

ASA rules require periodic review of all American Standards. In accord with this procedure, the 16mm and 8mm Motion Pictures Committee and the Standards Committee have recently reviewed Z22.50-1946 and reaffirmed it without change. The appropriate ASA committees have now approved this reaffirmation and the standard is therefore published on the following page as a validated 1952 standard.

American Standard

Reel Spindles

for 16-Millimeter Motion Picture Projectors

ASA

PH22.50-1952

1. Round Section

1.1 The round section of 16-mm motion picture projector reel spindles shall have a finished diameter of 0.312 ± 0.003 inch (7.925 ± 0.076 mm).

2. Square Section

2.1 The square section of 16-mm motion picture projector reel spindles, including finish, shall be 0.312 ± 0.003 inch (7.925 ± 0.076 mm) across the flats. Measurements across the flats shall be made in mutually perpendicular directions.

3. Cumulative Effect of Eccentricity

3.1 The cumulative effect of eccentricity of the round and square sections of the spindles, looseness and misalignment of the bearing, or other mechanical imperfections shall not cause the flange of a tight-fitting reel to depart from the ideal plane by more than 40 minutes of arc.

3.2 A suitable gage for determining the cumulative effect of eccentricity consists of a hub, with coaxial square and round holes whose respective sides and diameter are equal in length, and a flange of suitable stiffness whose diameter is equal to that of an 800-foot reel flange, 10.5 inches (266.7 mm). The flange should be permanently joined to the hub so that its face is perpendicular to the axis of the hub with not more than 0.003 inch (0.076 mm) runout. The hub shall be provided with a thumbscrew for clamping the hub to the reel spindle so that one side of the round and square holes shall come in contact with the corresponding round and square sections of the reel spindle.

4. Reel Position on Spindles

4.1 The design of spindles shall be such that reels are kept under constant lateral pressure against a shoulder on the spindle. The part forming this shoulder need not be integral with the spindle. However, in such event, it shall be securely fastened to the spindle so so that the two parts rotate together.

Approved March 19, 1946, by the American Standards Association

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Standards PH22.5, PH22.12 and PH22.93 Related to 16mm and 35mm Low-Shrink Film

Two REVISED American Standards and one Proposed Standard are published on the following pages for three month trial and criticism. All comments should be sent to Henry Kogel, SMPTE Staff Engineer, prior to April 1, 1953. If no adverse comments are received, the three proposals will then be submitted to ASA Sectional Committee PH22 for further processing as American Standards.

The introduction of safety base of a low-shrink type removes some of the problems of film dimensions but has introduced two slight difficulties. To take care of these difficulties the Film Dimensions Committee has recommended modifications in the dimensional standards for 16mm film (PH22.5 and PH22.12) and has introduced a new standard (PH22.93) for 35mm film to be used as negative material on the sprocket-type printer.

In the case of 16mm film the introduction of low-shrink type base produced an increase in the number of cases where film has jammed in the camera gate. Investigation showed this increase to be due to the fact that many camera manufacturers had produced gates which would pass film only if the width of the film was appreciably less than the upper limit (0.630 in.) of the cutting and perforating tolerance. Now, the low-shrink type of film, even though originally slit within these tolerances, would swell at high humidities just as much as the older type with the result that its width at the time of use might well exceed the tolerance. This trouble rarely occurred with the older type of film because its characteristics were such that it would shrink enough by the time it reached the camera to compensate for any possible swelling at high humidities. The Committee recommends, therefore, an alternate standard slitting width of 0.628 in. ± 0.001 in. to be used with low-shrink film.

The Committee calls special attention to the fact that the act of writing the standard this way does not represent a decrease in the actual width of film as used by the customer. Manufacturers of apparatus should not use this change in dimension as a reason for changing the width of film gates.

In the case of 35mm film the same reasoning might apply but since no actual difficulties have been reported, the Committee does not wish to make a change in the nominal width of the film. Another difficulty, however, has been introduced. This difficulty occurs only on film which is to be used on sprocket type printers.

It will be recalled that the negative film on a sprocket-type printer must be shorter in pitch than the positive film if the two are to travel together around the sprocket without slippage relative to each other. For most printers this difference in length corresponds to a shrinkage of about 0.3%. Now, the negative film, such as was formerly used when nitrate film base was generally used, would shrink to approximately this value by the time it was ready for making release prints. Not much difficulty was encountered, therefore, arising from the slippage between nega-

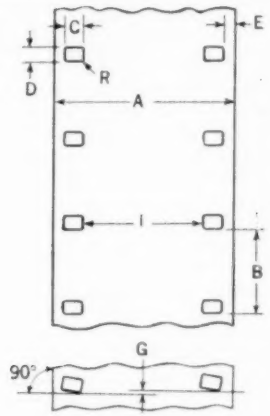
tive and positive films on sprocket-type printers. With low-shrink safety base, however, sufficient shrinkage did not occur. It was found desirable, therefore, to "pre-shrink" the film by perforating it at a slightly shorter pitch than that previously used. The pitch selected was 0.1866 in. This is approximately 0.2% less than standard pitch instead of 0.3% as required by theory. It is found in practice, however, that this pitch produces satisfactory prints even when no shrinkage at all has occurred and still allows a margin for any shrinkage that is likely to occur later. It also introduces a minimum change in the action of the film in the camera. Tests have shown that cameras can take film of this pitch quite as well as film of the standard pitch.

The case of master positive and duplicating negative is not completely solved by this new standard. Each one of these is used in the printer on the outside of the arc when the image is printed on to it and on the inside of the arc when the image is printed from it. No single pitch, therefore, can take care of both of these cases. In actual practice it is generally found satisfactory to use standard pitch for the master positive, short pitch for the duplicating negative and to do all the printing on continuous printers.—*E. K. Carver.*

Proposed American Standard
Dimensions for 16mm Double-Perforated Motion Picture Film

PH22.5

Revision of Z22.5–1947



Dimensions	Inches	Millimeters
*A	0.629 ± 0.001	15.98 ± 0.03
†B	0.3000 ± 0.0005	7.620 ± 0.013
C	0.0720 ± 0.0004	1.83 ± 0.01
D	0.0500 ± 0.0004	1.27 ± 0.01
*E	0.036 ± 0.002	0.91 ± 0.05
G	Not > 0.001	Not > 0.025
I	0.413 ± 0.001	10.490 ± 0.025
L‡	30.00 ± 0.03	762.00 ± 0.76
R	0.010	0.25

These dimensions and tolerances apply to negative and positive raw stock immediately after cutting and perforating.

*For low-shrink film as defined in Appendix 2, A shall be 0.628 ± 0.001 and E shall be 0.0355 ± 0.0020 in.

†In any group of four consecutive perforations, the maximum difference of pitch shall not exceed 0.001 in. and should be as much smaller as possible.

‡This dimension represents the length of any 100 consecutive perforation intervals.

NOT APPROVED

Proposed American Standard
Dimensions for 16mm Double-Perforated Motion Picture Film

PH22.5

Revision of Z22.5–1947

Appendix 1

The dimensions given in this standard represent the practice of film manufacturers in that the dimensions and tolerances are for film immediately after perforation. The punches and dies themselves are made to tolerances considerably smaller than those given, but owing to the fact that film is a plastic material, the dimensions of the slit and perforated film never agree exactly with the dimensions of the punches and dies. Shrinkage of the film, due to change in moisture content or loss of residual solvents, invariably results in a change in these dimensions during the life of the film. This change is generally uniform throughout the roll.

The uniformity of perforation is one of the most important of the variables affecting steadiness of projection.

Variations in pitch from roll to roll are of little significance compared to variations from one sprocket hole to the next. Actually, it is the maximum variation from one sprocket hole to the next within any small group that is important. This is one of the reasons for the method of specifying uniformity in dimension B.

Appendix 2

In the early days of 16mm film the safety base used for this film had the characteristic of shrinking very rapidly to a certain fairly definite amount and then not shrinking much more. Although this film tended to swell at high humidities, nevertheless the shrinkage that occurred in the package before the user received the film was always at least as great as any swell that might occur due to high humidities at the time of use. This meant that the user never encountered film, even at high humidities, that had greater width than that specified in the standards. This meant that camera and projector manufacturers seldom ran into trouble so long as their film gates would readily pass film at the upper limit of the slitting tolerances, namely 0.630 in.

Within the past few years, however, a safety base with lower shrinkage characteristics began to be used. Although this film was less susceptible than the previous film to swelling at high humidities, nevertheless the shrinkage characteristics were low enough so that this shrinkage did not always compensate for the swell at high humidities.

For this reason film slit at the mid point of the tolerance for width, namely 0.629 in., would occasionally swell at high humidities to such an extent that it would bind in film gates designed to pass film with the width of 0.630 in. The manufacturers, therefore, were compelled to slit at the lower edge of the tolerance permitted by the American Standard. Variations in their slitting width, however, sometimes produced film slit below the limits of the standard.

For this reason an alternate standard has been adopted for this low-shrink film in order that the manufacturers may slit within the standard and still produce film which does not exceed 0.630 in. even at high humidities.

For the purpose of this specification, low-shrink film base is film base which, when coated with emulsion and any other normal coating treatment, perforated, kept in the manufacturer's sealed container for 6 months, exposed, processed, and stored exposed to air not to exceed 30 days at 65 to 75 F and 50 to 60% relative humidity and measured under like conditions of temperature and humidity, shall have shrunk not more than 0.2% from its original dimension at the time of perforating. The final measurement should be made after conditioning the film for 24 hours to a humidity of 55 ± 5%.

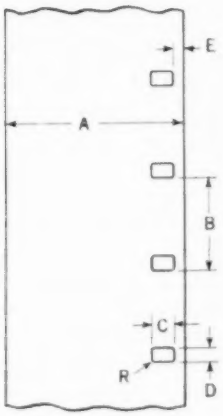
This definition of low-shrink film is to be used as a guide to film manufacturers, and departure therefrom shall not be cause for rejection of the film.

NOT APPROVED

Proposed American Standard
Dimensions for 16mm Single-Perforated Motion Picture Film

PH22.12

Revision of Z22.12-1947



Dimensions	Inches	Millimeters
*A	0.629 ± 0.001	15.98 ± 0.03
†B	0.3000 ± 0.0005	7.620 ± 0.013
C	0.0720 ± 0.0004	1.83 ± 0.01
D	0.0500 ± 0.0004	1.27 ± 0.01
E	0.036 ± 0.002	0.91 ± 0.05
L‡	30.00 ± 0.03	762.00 ± 0.76
R	0.010	0.25

These dimensions and tolerances apply to negative and positive raw stock immediately after cutting and perforating.

*For low-shrink film as defined in Appendix 2, A shall be 0.628 ± 0.001 and E shall be 0.0355 ± 0.0020 in.

†In any group of four consecutive perforations, the maximum difference of pitch shall not exceed 0.001 in. and should be as much smaller as possible.

‡This dimension represents the length of any 100 consecutive perforation intervals.

NOT APPROVED

Proposed American Standard
Dimensions for 16mm Single-Perforated Motion Picture Film

PH22.12

Revision of Z22.12–1947

Appendix 1

The dimensions given in this standard represent the practice of film manufacturers in that the dimensions and tolerances are for film immediately after perforation. The punches and dies themselves are made to tolerances considerably smaller than those given, but owing to the fact that film is a plastic material, the dimensions of the slit and perforated film never agree exactly with the dimensions of the punches and dies. Shrinkage of the film, due to change in moisture content or loss of residual solvents, invariably results in a change in these dimensions during the life of the film. This change is generally uniform throughout the roll.

The uniformity of perforation is one of the most important of the variables affecting steadiness of projection.

Variations in pitch from roll to roll are of little significance compared to variations from one sprocket hole to the next. Actually, it is the maximum variation from one sprocket hole to the next within any small group that is important. This is one of the reasons for the method of specifying uniformity in dimension B.

Appendix 2

In the early days of 16mm film the safety base used for this film had the characteristic of shrinking very rapidly to a certain fairly definite amount and then not shrinking much more. Although this film tended to swell at high humidities, nevertheless the shrinkage that occurred in the package before the user received the film was always at least as great as any swell that might occur due to high humidities at the time of use. This meant that the user never encountered film, even at high humidities, that had greater width than that specified in the standards. This meant that camera and projector manufacturers seldom ran into trouble so long as their film gates would readily pass film at the upper limit of the slitting tolerances, namely 0.630 in.

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For this reason film slit at the mid point of the tolerance for width, namely 0.629 in., would occasionally swell at high humidities to such an extent that it would bind in film gates designed to pass film with the width of 0.630 in. The manufacturers, therefore, were compelled to slit at the lower edge of the tolerance permitted by the American Standard. Variations in their slitting width, however, sometimes produced film slit below the limits of the standard.

For this reason an alternate standard has been adopted for this low-shrink film in order that the manufacturers may slit within the standard and still produce film which does not exceed 0.630 in. even at high humidities.

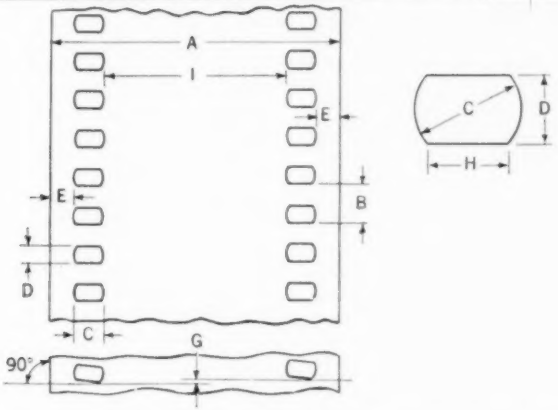
For the purpose of this specification, low-shrink film base is film base which, when coated with emulsion and any other normal coating treatment, perforated, kept in the manufacturer's sealed container for 6 months, exposed, processed, and stored exposed to air not to exceed 30 days at 65 to 75 F and 50 to 60% relative humidity and measured under like conditions of temperature and humidity, shall have shrunk not more than 0.2% from its original dimension at the time of perforating. The final measurement should be made after conditioning the film for 24 hours to a humidity of 55 ± 5%.

This definition of low-shrink film is to be used as a guide to film manufacturers, and departure therefrom shall not be cause for rejection of the film.

NOT APPROVED

Proposed American Standard
Dimensions for 35mm Motion Picture Short-Pitch Negative Film

PH22.93



Dimensions	Inches	Millimeters
A	1.377 ± 0.001	34.98 ± 0.03
B	0.1866 ± 0.0005	4.740 ± 0.013
C	0.1100 ± 0.0004	2.794 ± 0.01
D	0.073 ± 0.0004	1.85 ± 0.01
E	0.079 ± 0.002	2.01 ± 0.05
G	Not > 0.001	Not > 0.025
*H	0.082	2.08
I	0.999 ± 0.002	25.37 ± 0.05
L‡	18.66 ± 0.015	474.00 ± 0.38

These dimensions and tolerances apply to low-shrink negative raw stock immediately after cutting and perforating.

This film is used for motion picture negatives and certain special processes.

* A calculated value for a dimension not measured routinely in production.

‡ This dimension represents the length of any 100 consecutive perforation intervals.

This standard is based on American Standard Z22.34–1949 and differs only in the values of B and L and the addition of a second Appendix.

NOT APPROVED

Proposed American Standard
Dimensions for 35mm Motion Picture Short-Pitch Negative Film

PH22.93

Appendix 1

The dimensions given in this standard represent the practice of film manufacturers in that the dimensions and tolerances are for film immediately after perforation. The punches and dies themselves are made to tolerances considerably smaller than those given, but owing to the fact that film is a plastic material, the dimensions of the slit and perforated film never agree exactly with the dimensions of the punches and dies. Shrinkage of the film, due to change in moisture content or loss of residual solvents, invariably results in a change in these dimensions during the life of the film. This change is generally uniform throughout the roll.

The uniformity of perforation is one of the most important of the variables affecting steadiness of projection.

Variations in pitch from roll to roll are of little significance compared to variations from one sprocket hole to the next. Actually, it is the maximum variation from one sprocket hole to the next within any small group that is important.

Appendix 2

Most motion picture film is printed on sprocket-type printers. Maximum steadiness and definition are secured on a sprocket-type printer when the negative film is somewhat shorter in pitch than the positive stock.

For many years, this difference in pitch has come about due to shrinkage of the negative film base on processing and aging.

There are currently becoming available new low-shrink film bases which do not shrink sufficiently to provide the necessary pitch differential between negative and print stock for proper printing on sprocket-type printers. This standard is intended to give dimensions for perforating low-shrink film material so that it will have, as nearly as possible, optimum dimensions at the time of printing.

For the purpose of this specification, low-shrink film base is film base which, when coated with emulsion and any other normal coating treatment, perforated, kept in the manufacturer's sealed container for 6 months, exposed, processed, and stored exposed to air not to exceed 30 days at 65 to 75 F and 50 to 60% relative humidity and measured under like conditions of temperature and humidity, shall have shrunk not more than 0.2% from its original dimension at the time of perforating. The final measurement should be made after conditioning the film for 24 hours to a humidity of 55 ± 5%.

This definition of low-shrink film is to be used as a guide to film manufacturers, and departure therefrom shall not be cause for rejection of the film.

NOT APPROVED

73d Semiannual Convention

A meeting of the Papers Committee at Washington on October 9, during the 72d Convention, laid general plans for the Spring Convention to be held at the Los Angeles Statler, April 27 – May 1. Several aims were espoused and some sessions planned. Inasmuch as the National Association of Radio and Television Broadcasters will meet at Los Angeles during the early part of that week, the SMPTE television sessions will be held on Thursday and Friday, contrary to the arrangement of recent convention programs. The arrangement of all the sessions will be shown in the Advance Notice of the Convention scheduled to be mailed to members on March 2d.

Deadlines established by Papers Committee Chairman Bill Rivers and 73d Program Chairman Ralph Lovell are: Authors' Forms and Abstracts due on February 16; manuscripts due on March 23.

Blank forms can now be obtained from anyone on the Papers Committee, but it is preferable that you work with the one nearest you. The complete roster of the Committee will be published in the next *Journal*.

The Chairman and Vice-Chairmen are:

Chairman: W. H. Rivers, Eastman Kodak Co., 342 Madison Ave., New York 17.

73d Convention Program Chairman: Ralph E. Lovell, 2743 Veteran Ave., West Los Angeles 64, Calif.

For Washington: J. E. Aiken, 116 N. Galveston St., Arlington 3, Va.

For Chicago: Geo. W. Colburn, 164 N. Wacker Dr., Chicago 6, Ill.

For High-Speed Photography: Carlos H. Elmer, 410B Forrestal St., China Lake, Calif.

For Canada: G. G. Graham, National Film Board of Canada, John St., Ottawa, Canada.

For New York: E. Arthur Hungerford, Jr., Campfire Rd., Chappaqua, N.Y.

Awards

The Society serves its field in one way, among others, by an attempt to recognize formally important contributions by individuals. Several awards are conferred annually upon those whose work has been considered significant in their particular fields of interest. Those who were selected during 1952 were presented awards during the Fall Convention of the Society in Washington, D.C. Their names and awards are listed here.

As has been done in past years there were published earlier this year, in April, the recommendations, citations and former recipients of the Progress Medal Award, the Samuel L. Warner Memorial Award, the Journal Award and the David Sarnoff Award.

New Fellows of the Society

President Mole formally inducted the following as new Fellows of the Society:

John Arnold, Metro-Goldwyn-Mayer Studios, Culver City, Calif.

E. E. Blake, Council Kinematograph Manufacturers Association of Great Britain and Kodak Ltd., London

O. L. Dupy, Metro-Goldwyn-Mayer Studios, Culver City, Calif.

Karl Freund, Photo Research Corp., Burbank, Calif.

Edgar Gretener, Dr. Edgar Gretener A.G., Zurich, Switzerland

W. T. Hanson, Jr., Eastman Kodak Co., Rochester, N.Y.

C. E. Heppberger, National Carbon Co., Chicago

President Peter Mole is at the left. Award recipients next in order shown are: Axel G. Jensen, the David Sarnoff Gold Medal Award; Wadsworth Pohl who accepted the Samuel L. Warner Memorial Award on behalf of Herbert T. Kalmus; John I. Crabtree, the Progress Medal; and D. L. MacAdam, the Journal Award.

Henry J. Hood, Eastman Kodak Co., Rochester, N.Y.
A. G. Jensen, Bell Telephone Laboratories, Murray Hill, N.J.
Klaus Landsberg, KTLA Television Productions, Hollywood, Calif.
E. H. Reichard, Consolidated Film Industries, Hollywood, Calif.
A. C. Robertson, Eastman Kodak Co., Rochester, N.Y.
Ben Schlanger, Consultant, New York
John G. Stott, Du-Art Film Laboratories, New York
E. W. Templin, Westrex Corp., Hollywood, Calif.

Journal Awards

The Journal Award went to D. L. MacAdam of the Research Laboratory, Eastman Kodak Co., Rochester, N.Y., for his "Quality of Color Reproduction" which was published in May 1951.

Franklin C. Williams of the Research Laboratory, Eastman Kodak Co., Rochester, N.Y., received honorable mention for his "Current Problems in the Sensitometry of Color Materials and Processes" which appeared in the *Journal* for January 1951.

Honorable mention was conferred on Otto H. Schade, Tube Dept., Radio Corporation of America, Harrison, N.J., for "Image Gradation, Graininess and Sharpness in Television and Motion Picture Systems — Part I: Image Structure and Transfer Characteristics" which appeared in the February 1951 *Journal*.

William C. Kunzmann who has been Convention Vice-President since time memorial of this Society was presented a gold card of Life Membership "in grateful recognition of 36 years of enthusiastic participation and inspired leadership in the work of the Society." Shown in the usual order are Editorial Vice-President John Frayne, Bill Kunzmann and President Peter Mole. Next are pictures salvaged from old lantern slides depicting Bill and his activities at a somewhat earlier stage of his career.

New Society Formed

At a meeting at the Hotel Astor, New York, October 2nd, 3rd and 4th, the Society of Motion Picture Engineers was formed. The membership includes men who are closely connected with the development of the engineering and of motion picture work and the society has for its main object the standardization of the industry. W. C. Kunzman of the Sales Department is a member of the Committee on Illumination Development. At the organization meeting C. Francis Jenkins, of Washington, D. C., was elected president. The next meeting of the society will be held at Atlantic City some time in March, at which a number of papers will be presented.

Progress Medal

John I. Crabtree, head of the photographic chemistry department of Kodak Research Laboratories, received the Progress Medal "for his outstanding contribution in the field of photographic chemistry, motion picture processing and processing equipment." The formal presentation was made by D. B. Joy, Chairman of the Progress Medal Award Committee, as follows:

"He was born and educated in England and started his professional work as a Research Chemist with the Eastman Kodak Company in Rochester in 1913. He became a naturalized United States citizen in 1924. He founded the photographic chemistry department of Kodak Research Laboratories in 1913 and is still its head. From 1916 to 1938 he also was in charge of the motion picture film developing department. He has conducted and supervised research in many fields of photography including the chemistry of development and fixation, methods of processing photographic materials, the use of desensitizers, stains and markings on photographic materials, preparation and use of flash powders, tinting and toning of lantern slides and motion picture films, the corrosive effect of photographic solutions on photographic apparatus, tropical processing, silver recovery, compounding of package chemicals, storage of photographic records, and effective methods of washing photographic materials. He has devoted much of his attention to the technique of motion picture processing.

"A particularly important piece of research concerned the chemistry of the stop bath and especially of the fixing bath. Recent very valuable work has been done in his department on agents for "sequestering" calcium and iron in developers, on replenishment systems for developers, on rapid processing at high temperatures, on the preparation of concentrated liquid developers, and on the design of special processing equipment.

"He has been author and co-author of some 150 papers and two books and has been granted 30 United States patents, covering a wide variety of subjects. His articles have been published in many countries and several have been reprinted as handbooks.

"He has been a member of this Society for more than 25 years. He was President of the Society in 1930 and 1931, during which time he was largely instrumental in establishing the *Journal* on a monthly basis, the system of Sustaining Memberships, the Journal Award and this Progress Medal Award. His vivid discussions of papers have enlivened many a Society Meeting. He was a member of the Board of Governors for many years and served as Chairman of several committees and of the Board of Editors.

"He has been an active member of many other scientific societies.

"For nearly forty years, John I. Crabtree has worked diligently at his chosen profession of photographic chemistry. Much of the advancement of knowledge of general photographic and motion picture processing reactions and techniques can be traced directly to his researches and that of colleagues under his supervision."

Samuel L. Warner Memorial Award

Herbert T. Kalmus, President and General Manager of Technicolor Motion Picture Corp., was awarded the Samuel L. Warner Memorial Award. President Mole first spoke of the awarding as follows:

"As one who comes from Hollywood, I am taking the liberty of saying a few words of my own on this award. In the early twenties, an obscure scientist was struggling in Boston to perfect a color formula for motion picture film which was destined one day to revolutionize the motion picture industry. This scientist, against innumerable odds and financial setbacks, was persistent, however, and finally conquered these obstacles to give to the world of motion pictures natural color as we know it today — Technicolor.

"For bringing color to motion pictures, Herbert Kalmus must be credited as one of the savers of the motion picture boxoffice. Color came at a time when the public was tiring

of black-and-white films and both producers and exhibitors needed something new to attract patrons to the theater. As one who richly deserves this high honor from our Society, Dr. Herbert T. Kalmus now receives the Samuel L. Warner Memorial Award, accepted on his behalf by Mr. Wadsworth Pohl, his associate."

The citation prepared by the Committee, of which Glenn L. Dimmick is Chairman, was as follows:

"No man, over the past 20 years, has so consistently contributed to the technical quality of motion pictures as Dr. Herbert T. Kalmus. Almost without exception, the biggest grossers since *Gone With the Wind* have been pictures made in 'Color by Technicolor.' Indeed, good color of any type, in the eyes of the public, is called Technicolor. It is today the standard by which other color processes are judged.

Dr. Kalmus, over the years, has maintained the highest practicable color standards and has always recognized the value of research and engineering toward this end. While maintaining these standards of quality, the cost of not only release prints but set lighting costs have been reduced step by step as faster-type emulsions were made available to picture producers. During the last war, Technicolor's ability to 'blow up' the 16mm Kodachrome footage of the Armed Forces to 35mm film for showing to the public in theaters was a great aid to morale and public information in those critical times. If it had not been for the war and its retarding effect on civilian development, Technicolor's single-film Monopack would have been available sooner to supplant the three-negative process. Dr. Kalmus hoped as early as 1940 to bring it into wide use and its availability will undoubtedly be greater in the immediate future.

"Technicolor's perfection in the last few years of the inbibition process of making top quality 16mm color prints in quantity at reasonable cost is a distinct contribution to the 16mm field. The quality of both picture and sound of these prints and the development of the techniques of making the separate sound negatives for mass production by the 35mm32mm method contributes a great deal to the excellence of the 16mm sound.

"Dr. Kalmus, through his personal and active direction of his company, has been instrumental in creating the boxoffice truism that 'good color makes a good picture a still better picture.'

"For further information on Dr. Kalmus, I refer to the article in the Saturday Evening Post of October 22, 1949, 'Mr. Technicolor,' by Frank J. Taylor. Dr. Kalmus was given the Society's Progress Medal for 1938 and the citation was presented on pages 556 to 560 of the December 1938 *Journal*."

David Sarnoff Gold Medal Award

Axel G. Jensen was presented the David Sarnoff Gold Medal Award "for his manifold contributions to the promulgating of monochrome and color television engineering standards, and for his work on the improvement of the quality of television pictures obtained from motion picture film." Pierre Mertz was Chairman of the Committee which made this citation:

"Axel G. Jensen was born and educated in Copenhagen, Denmark, until coming to Columbia University in 1921 for graduate work.

"His professional career began in 1922 when he joined what is now the Research Department of the Bell Telephone Laboratories. Since 1938 he has been engaged in research work in television equipment and systems. In particular he has been responsible for the development of a high-quality testing link which, employing motion picture film, can be used as a research tool for the evaluation of methods and systems for television transmission, and of the influence of component elements on the transmission quality. As a part of this he has been in charge of work on a succession of test film scanners, culminating in a development which was presented before the Society last year. He has

also been responsible for considerable miscellaneous research work on electrical, optical and visual problems connected with television systems.

"Mr. Jensen has taken part in many industry committees, particularly many committees promulgating engineering standards for television as a result of their deliberations. He took an active part in the committee work of the first NTSC in 1941, from which came the engineering standards in monochrome television which are still largely in use today. He continued to take an active part in the television activities of RTPB from 1944 to 1948, and of panels of JTAC. In the second NTSC, established in 1950, he has been a member of several panels and is now vice-chairman of Panel 12 on Color System Analysis. He has been chairman of the IRE-RTMA-SMPTE Television Coordinating Committee in 1950–51; vice-chairman of the IRE Standards Committee in 1949–50, and chairman in 1951; chairman of the IRE Television Committee in 1948; and chairman of the IRE Television Systems Committee in 1949–51. He was elected a Fellow of the IRE in 1942, and Governor of the SMPTE in 1952. He has just finished an extensive lecture tour, in the United States and Europe, describing the fundamentals of color television transmission and of the various systems which can be used to achieve it. In the course of it he was awarded the G. A. Hagemann Gold Medal by the Royal Technical University of Denmark.

"In the Bell Telephone Laboratories Mr. Jensen has recently been promoted from Engineer in Charge of Television Research, to Director of Television Research. He holds ten issued patents and has published a number of papers, the most recent being, in coauthorship with R. E. Graham and C. F. Mattke, on a "Continuous Motion Picture Projector for Use in Television Film Scanning," in the January 1952 *Journal*."

Board of Governors Meeting

Meeting on October 5 at Washington, the Board gave a considerable portion of its attention to information from the Executive Committee, reported by Executive Vice-President Barnett and Executive Secretary Nemec.

The publication of proposed amendments to the Bylaws in the August Journal was noted. (These were voted approved at the Society's Business Meeting on October 6.) Plans for continued study of test film costs were briefly discussed and the Society's success in restoring the mailing of the *Journal* to the proper (lowest cost) category was noted.

A lively, detailed and constructive discussion about membership service quality, costs and promotion held the Board's attention for nearly two hours, with every officer and governor contributing reports of the needs of television, film producer, high-speed photography and other interests. Specific suggestions in the notes for follow-up by the staff were tabbed as from Messrs. Aiken, D'Arcy, Heppberger, Mole, Neu, Shaner, Sponable, Stifle and Townsley. (Material helpful to television engineers has since been planned. The complete roster of member and nonmember high-speed photography registrants has been mimeographed and circulated to the High-Speed Photography Committee for their help in obtaining new members. The brochure describing the Society for prospective members is now revised.) A six-page membership cost study was read by Executive Secretary Nemec on behalf of the Executive Committee. This study was accepted as the record of the past three years and as a basis for a continuing record and guidance for the Board.

Reports by the respective vice-presidents were welcomed and approved as in good order by the Board.

A change in the Administrative Practices was approved as presented as follows in the report by Editorial Vice-President Frayne:

"Because the Board of Editors as presently comprised of 18 members is no more than adequate, the Administrative Practices should be brought up to date by changing the present stipulation of 'seven Fellows and Active members,' to: 'The Editorial Vice-President upon taking office shall appoint the chairman of the Board of Editors and the members of the Board. The latter shall consist of not less than 12 members of the Society in good standing and shall be representative of all the various branches and interests of the motion picture and television industry.' "

Reports of Section Chairmen Heppberger, Shaner and Stifle contained a new element in greater strength: regional organizations established at San Francisco and Dallas and proposed in Atlanta. (A report of the San Francisco Subsection has been given in the October 1952 *Journal* and a brief report of the Atlantic Coast Section Regional Meeting was published in the September 1952 *Journal*.)

New Officers

At the close of the October 5 Board Meeting, Secretary Robert M. Corbin reported the results of the Society election for 1952. The following were elected for two-year terms beginning January 1, 1953:

Herbert Barnett, President
John G. Frayne, Executive Vice-President
Norwood L. Simmons, Editorial Vice-President
John W. Servies, Convention Vice-President
Edward S. Seeley, Secretary
Frank E. Carlson, Governor, Central
Gordon A. Chambers, Governor, East
LeRoy M. Dearing, Governor, Pacific
William A. Mueller, Governor, Pacific
Charles L. Townsend, Governor, East
Malcolm G. Townsley, Governor, Central

By action of the Board of Governors during its previous meeting in July, Henry Hood was appointed to fill a vacancy in the office of Engineering Vice-President that was created by the resignation of F. T. Bowditch. Henry's term extends to December 31, 1953.

The Section elections made the following officers and new members of the Board of Managers:

Atlantic Coast Section

William H. Offenhauser, Jr., Chairman
Emerson Yorke, Secretary-Treasurer
Russell C. Holslag, Manager, 1953–1954
Milton H. Searle, Manager, 1953–1954
R. T. Van Niman, Manager, 1953–1954

Central Section

C. E. Heppberger, Chairman, reelected
James L. Wassell, Secretary-Treasurer, reelected
Paul Ireland, Manager, 1953–1954
William P. Kusak, Manager, 1953–1954
John S. Powers, Manager, 1953–1954

Pacific Coast Section

Vaughn C. Shaner, Chairman, reelected
Philip G. Caldwell, Secretary-Treasurer, reelected
Ralph Lovell, Manager, 1953–1954
Hollis Moyse, Manager, 1953–1954
Herbert Pangborn, Manager, 1953–1954

K. Kenneth Miura

The Student Chapter at the University of Southern California earlier this year elected K. Kenneth Miura its Chairman, and Richard Polister its Secretary-Treasurer.

Richard Polister

Organization of the Southwest Subsection

Activities of the recently formed Southwest Subsection began formally on the evening of October 23 in the studios of WBAP-TV, Fort Worth, Texas. C. E. Heppberger presided over the meeting and advised about the operation of a subsection. There were present 13 members and 23 guests.

Elected as the subsection's first roster of officers were:

Bruce Howard, Chairman;
Hugh V. Jamieson, Jr., Vice-Chairman and Secretary-Treasurer;
I. L. Miller, Program Chairman; and
George Mayer, Membership Chairman.

Future meetings are tentatively scheduled:

January 16, Friday evening, in Dallas;
March 16, Monday evening, in Fort Worth; and
May 20, Wednesday evening, in Dallas.

Members will be advised by letter confirming the dates and exact place of the meetings.—*Hugh V. Jamieson, Jr.*, 3825 Bryan St., Dallas 4, Tex.

Engineering Activities

72d Convention This is a continuation of the report on the meetings of Engineering Committees at the 72d Convention in Washington, D.C. See the November 1952 *Journal* for the first part of this story.

16mm and 8mm Motion Pictures Six American Standards, listed below, have been under active review for some time:

PH22.9, 16mm Double-Perforated Motion Picture Film — Usage in Camera;
PH22.10, 16mm Double-Perforated Motion Picture Film — Usage in Projector;
PH22.15, 16mm Single-Perforated Motion Picture Film — Usage in Camera;
PH22.16, 16mm Single-Perforated Motion Picture Film — Usage in Projector;
PH22.21, 8mm Motion Picture Film — Usage in Camera;
PH22.22, 8mm Motion Picture Film — Usage in Projector.

At this meeting it was agreed to draft further revisions of the first two standards, eliminate "guided edge" specification from the next two standards, and approve the last two standards without further change.

The ballot on the proposed standard, A and B Windings of 16mm Raw Stock Film, PH22.75, was reported as virtually complete without any negative votes. The ballot was therefore closed with an affirmative recommendation to the Standards Committee for further processing as an American Standard.

Magnetic Recording Subcommittee The widespread development and use of magnetic sound tracks demand a companion test film and standards program. Such a program, under way for some time, has now been launched with full force.

The magnetic recording proposals for 16mm and 35mm–17½mm film, PH22.86 and PH22.87, have cleared all the appropriate Society committees and are presently under review by ASA Sectional Committee PH22.

Agreement was reached on the dimensions of the magnetic coating of the 8mm proposal, PH22.88, for immediate consideration by the Sound Committee.

Similar approval was given to five proposed standards on magnetic test films, listed below:

SMPTE 509, 16mm Magnetic Flutter Test Film;
SMPTE 510, 35mm and 17½mm Magnetic Flutter Test Film;
SMPTE 511, Azimuth Alignment Test Film for 17½mm and 35mm Film With Magnetic Coating;
SMPTE 512, Azimuth Check Loop on 17½mm and 35mm Film With Magnetic Coating;
SMPTE 513, Azimuth Test Film for Fully Coated Magnetic 16mm Single-Perforated Motion Picture Film.

A subcommittee was then formed to study existing magnetic recording equipment with a view toward standardizing the reproducer characteristics.

Finally, with an eye toward the future, attention was called to the potentialities of half photographic/half magnetic track on 16mm film and magnetic track substituted for photographic on 35mm film.

Sound This meeting followed on the heels of the above Subcommittee meeting but in actuality the two meetings were held jointly. The Sound Committee now approved for letter ballot the six proposals approved by the Subcommittee and a seventh on 200-mil magnetic coating of 16mm single perforated film (SMPTE 544) submitted by the Subcommittee some time prior to this meeting.

In addition it was agreed to revise the three test film standards listed below. The revision would permit elimination of the identification leader and substitution of titles printed lengthwise in the picture area. This would increase the usable test film footage by about 25% without increasing its cost.

Z22.42-1946, 16mm 5000- and 7000-Cycle Sound Focusing Test Films;
Z22.45-1946, 16mm 400-Cycle Signal Level Test Films;
Z22.57-1947, 16mm Buzz Track Test Films.

Stereo This committee was formed in March 1952 with immediate attention devoted to development of a standard nomenclature and compilation of a bibliography. Prior to this first meeting the committee was very active in nomenclature activity via the mails. The entire meeting was therefore devoted to reviewing this activity and working out word for word the meanings of some of the more controversial, complex terms.

In briefly commenting on the bibliography project, John Norling, Chairman, stated that progress was being made and that a first draft would soon be issued to the committee for review.

Television Film Equipment This meeting had been called for only one reason: to expedite action on dimensional standards for the recorded and reproduced area of televised motion pictures. Differences had developed between East and West Coast thinking on this question which had prevented standardization to date.

The advantages and disadvantages of both proposals were thoroughly aired and a compromise proposal was offered for consideration. It was finally agreed to submit the latter proposal for letter ballot of the full committee. The vital dimensions of all three proposals are:

35 mm	*Record*	*Reproduce*
East	.609 × .812	.582 × .776
West	.619 × .825	.600 × .800
Compromise	.612 × .816	.594 × .792
16mm		
East	.288 × .384	.270 × .360
West	.288 × .384	.279 × .372
Compromise	.285 × .380	.276 × .368

Color This was the first meeting of this committee under its new Chairman, Dr. J. P. Weiss. The committee reviewed the state of the art and concluded that color was still in the early stages of development, which precludes any standards work at this time. It was noted, however, that comprehensive reports on various aspects of the field — for example, the published report "Principles of Color Sensitometry" — are considered very useful and desirable, and plans were made to further stimulate such activity.

High-Speed Photography A high priority was given to the question of developing a dictionary of terms peculiar to high speed photography and a subcommittee headed by Morton Sultanoff was appointed to begin active work on this.

The ASA Exposure Index also came up for discussion and it was considered highly desirable to extend film ratings to cover the range of exposures from a millisecond to a microsecond. This is no simple matter and the question was referred to ASA Sectional Committee PH2 for study and action.

The meeting closed with Carlos Elmer accepting the responsibility of the high-speed photography papers program for the Spring Convention in Los Angeles.

Meeting Reports For those who are interested in more detailed information concerning any of the above reported engineering committee meetings, a copy of the particular meeting report is available upon request.—*Henry Kogel*, Staff Engineer.

Book Reviews

Storage Tubes and Their Basic Principles

By M. Knoll and B. Kazan. Published (1952) by John Wiley, 440 Fourth Ave., New York 16. 143 pp. 34 illus. 6 × 9 in. Price $3.00.

Presumably the first text devoted exclusively to storage tubes, this book is useful to anyone concerned with the field. Of particular interest to television and motion picture engineers is the treatment of the iconoscope, the image orthicon and their relatives as particular cases of the genus storage-tube.

The writers first treat fundamentals, the electron bombarded "floating" surface, then definitions and basic operational methods. This is followed by a lucid treatment of the details of 23 individual storage tubes, suitably classified as to type. Ninety-nine references comprise the Bibliography, with the helpful innovation of a brief resume of the gist of each. Besides providing additional information this prevents "wild-goose-chases" after apparently promising titles.

Because the tubes are each treated in the same methodical manner, similarities and differences are easily grasped and can be quickly located when the book is used as a reference work. Storage tubes suitable for use with electronic computers are, of course, included, including the interesting case of the kinescope with the external electrode of metal foil.

Co-author Knoll is well known in the field and is responsible for four tubes that are treated impartially along with the rest.

The book is devoid of mathematical expressions, this aspect being treated in many of the cited references. Informative circuit diagrams and the essentials of construction of the tubes are given.

In view of the modest price, anyone who must have an understanding of these devices can hardly afford to be without the book. — *Harry R. Lubcke*, Consulting Engineer, 2443 Creston Way, Hollywood 28, Calif.

1952-53 Motion Picture and Television Almanac

Published (1952) by Quigley Publications, 1270 Sixth Ave., New York 20, N.Y., i-l + 1010 pp. (including advt.), thumb indexed, 6 × 9 in. Price $5.00.

This is another in the imposing procession of these annual reference volumes, this one giving an increased attention to the television field. Much of the preliminary work and planning for this volume was done by the late Maurice D. Kann who died on May 15, 1952.

With from three to eleven subsections where appropriate, the volume contains these sections:

Who's Who in Motion Pictures and Television
Corporations
Theatre Circuits
Drive-In Theatres
Television and Radio
Pictures
Services
Theatre Equipment Services and Materials
Organizations
The Government Case
Codes and Censorship
The World Market
The Industry in Great Britain
The Press
Non-Theatrical Motion Pictures

Although not a technical or engineering book, this is a valuable and obvious source for data on many business and facilities aspects of the Society's field as well as a help in another amusement activity — settling a discussion.—V.A.

High Speed Photography Issue

This is a special number of the Scientific Section of *The Photographic Journal* for Sept.-Oct. 1952. The release describing this issue advises:

"It is claimed that this publication brings this very important subject completely up to date and it is a source of reference which every firm, government department, laboratory, educational insti-

tution, and individual interested in this field should have.

"It is quite obvious that a number of scientific workers and institutions, not directly specializing in photography and the kindred sciences, do not yet realize the necessity of maintaining a complete set of "Section B" of *The Photographic Journal*. With the approach of the Society's Centenary — 1953 — [this point should be emphasized]. Since its foundation on 20 January 1853, this world-wide organization has fostered all applications of photography, kinematography, photoengraving, and radiography since their very inception as we know them today. We confidently expect wide recognition of the work performed by this Society during the past one hundred years."

Those who attended the International Symposium on High-Speed Photography at the SMPTE Convention in October will recognize at least two respected acquaintances among the contributors to *The Photographic Journal's* special issue:

R. H. J. Brown, "Flash Cinematography"
W. D. Chesterman and G. T. Peck, "A Synchronized Flash-Discharge System for High-Speed 35mm Cinematography"
J. S. Courtney-Pratt, "Image Converter Tubes and Their Application to High Speed Photography"
R. A. Chippendale, "Image Converter Techniques Applied to High Speed Photography"
K. D. Froome, "An Electronically Operated Kerr Cell Shutter"
J. M. Meek and R. C. Turnock, "Electro-Optical Shutters as Applied to the Study of Electrical Discharges"

This issue is noted on its cover as costing five shillings. Annual rates and other information should be requested from The Royal Photographic Society, 16 Princes Gate, London, S.W.7.

Current Literature

The Editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic or microfilm copies of articles in magazines that are available may be obtained from The Library of Congress, Washington, D.C., or from the New York Public Library, New York, N.Y., at prevailing rates.

American Cinematographer

vol. 33, Aug. 1952

Hollywood Launches 3-D Film Production (p. 336) *J. Biroc*
The Vistascope . . . New Tool for Motion Picture Production (p. 338) *L. L. Ryder*
"Anistration" . . . Streamlined Animation Technique (p. 340) *A. Rowan*
Background Projection Photography (p. 342) *C. L. Anderson*
High-Speed Cinematography (p. 343) *J. H. Waddell*

vol. 33, Sept. 1952

WarnerColor — Newest of Color Film Process (p. 384) *E. B. DuPar*
Miniatures in Motion Picture Production (p. 386) *A. Rowan*
Camera Fill Lights (p. 388) *F. Foster*
Lighting for High-Speed Motion Pictures (389) *J. H. Waddell*
Wheels that Still Turn Backward (p. 390) *R. H. Cricks*
Filming the TV Dramatic Featurette (p. 392) *H. A. Lightman*
Now . . . Magnetic Sound for All Cine Films (p. 394) *J. Forbes*

Bild und Ton

vol. 5, Sept. 1952

Die Projektierung eingebauter Lichtspieltheater in Moskau (p. 271)
Schäden am 35-mm-Kino-Film (p. 279) *H. Mager*

British Kinematography

vol. 21, July 1952

Magnetic Sound on 16mm Edge-Coated Film; A Short Review of a Current Trend (p. 15)

vol. 21, Sept. 1952

A Test to Measure the Flammability of Kinematograph Safety Film (p. 61) *R. W. Pickard*
Latensification (p. 67) *P. Raibaud*

Electrical Communication

vol. 29, Sept. 1952

Low-noise Traveling-Wave Tube (p. 234) *A. G. Peifer, P. Parzen and J. H. Bryant*

Electronics

vol. 25, Aug. 1952

Improving TV System Transient Response (p. 110–113) *John Ruston*

vol. 25, Oct. 1952

A Phase Indicator for Color Television (p. 112) *K. Schlesinger and L. W. Nero*

International Projectionist

vol. 27, July 1952

Heart of the Projector Mechanism (p. 5) *R. A. Mitchell*

Fox Unveils Eidophor, Arc-Lit Color TV (p. 14)

vol. 27, Aug. 1952

Heart of the Projector Mechanism, Pt. II (p. 8) *R. A. Mitchell*

vol. 27, Sept. 1952

Heart of the Projector Mechanism, Pt. III (p. 5) *R. A. Mitchell*

Stereosound Enhances Eidophor TV (p. 11)

Kino-Technik

no. 7, July 1952

Der neue Tonschmalfilmprojektor Elektor 16T3 (p. 171)

Infrarotfilm in der wissenschaftlicken Kinematographie (p. 172) *J. Rieck*

Jetzt auch Stereofilm im eigenen Heim (p. 177) *H. Lueschen*

no. 9, Sept. 1952

Berlins Anteil an der deutschen Filmindustrie (p. 208) *H. Muting*

Aus der Arbeit der Berliner kinotechnischen Betriebe (p. 209)

Akustik im Tonfilmtheater (p. 214) *W. Bausch*

"Filmosound 202" schafft neue Moglichkeiten fur den 16-mm-Film (p. 216) *W. Beyer*

Tonaufnahmegerate und Mischanlage der Western Electric (p. 218)

Storungen bei der Vorfuhrung von Tonfilmen (p. 221) *K. Braune and H. Tummel*

Motion Picture Herald

vol. 188, Oct. 1952

(Better Theaters Section)

How the New Four-Inch Lenses Give a Brighter Picture (p. 10) *G. Gagliardi*

Getting into the Drive-in Business, Pt. 8, Planning the Main Building (p. 11) *W. P. Smith*

This is Cinerama on Broadway (p. 14)

Proceedings of the I.R.E.

vol. 40, Aug. 1952

Requisite Color Bandwidth for Simultaneous Color-Television Systems (p. 909–912) *Knox McIlwain*

Elimination of Moire Effects in Tri-Color Kinescopes (p. 916–923) *E. G. Ramberg*

Cathode-Ray Picture Tube With Low-Focusing Voltage (p. 937–945) *C. S. Szegho*

vol. 40, Oct. 1952

An Experimental System for Slightly Delayed Projection of Television Pictures (p. 1177) *P. Mandel*

Gamma Correction in Constant Luminance Color Television Systems (p. 1185) *S. Applebaum*

Radio and Television News

vol. 48, Aug. 1952

Cinemagnetic Recording (p. 46) *A. C. Blaney*

The TV Picture Tube (p. 50) *W. Buchsbaum*

Tele-Tech

vol. 11, Oct. 1952

Television Control Room Layout (p. 48) *R. D. Chipp*

SMPTE Lapel Pins

The Society will have available for mailing after September 15, 1952, its gold and blue enamel lapel pin, with a screw back. The pin is a ½-in. reproduction of the Society symbol — the film, sprocket and television tube — which appears on the *Journal* cover.

The price of the pin is $4.00, including Federal Tax; in New York City, add 3% sales tax.

Obituary

Percy D. Brewster died on October 27 at his home at East Orange, N.J., after a long illness. He had retired 12 years ago. His work as a motion picture engineer led him to credit as the inventor of several color photographic processes, with 360 patents granted to him. He was President of the Brewster Color Film Corp. of Newark, N.J., and of the former Revelation Film Corp. of London.

He became a member of the Society of Motion Picture Engineers in 1929 and was made a Fellow in 1934. He was cited by the Royal Society of London for his work in color photography and was the first to make a color photograph of President Wilson. He was graduated from Cornell University in 1906.

New Members

The following members have been added to the Society's rolls since those last published. The designations of grades are the same as those used in the 1952 MEMBERSHIP DIRECTORY.

Honorary (H) Fellow (F) Active (M) Associate (A) Student (S)

Adair, George P., Consulting Engineer, George P. Adair Engineering Co., 1610 Eye St., N.W., Washington 6, D.C. (M)

Adler, Benjamin, Engineer, Adler Communications Laboratories, 1 LeFevre La., New Rochelle, N.Y. (M)

Bras, Rene, President, Science Pictures, Inc., 5 E. 57 St., New York, N.Y. (M)

Diner, Leo, Motion Picture Producer, 332 Golden Gate Ave., San Francisco, Calif. (M)

Ewing, Jasper G., Jr., Partner, Jasper Ewing & Sons. **Mail:** 725 Poydras St., New Orleans, La. (A)

Friedman, Jacob, Photographer, Emerson Electric Manufacturing Co. **Mail:** 7010 Tulane, University City 5, Mo. (A)

Gallagher, James C., President, Gallagher Films, Inc. **Mail:** 137 N. Oakland Ave., Green Bay, Wis. (A)

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Inglis, Andrew F., Radio Engineer, McIntosh & Inglis. **Mail:** 4619 Norwood Dr., Chevy Chase, Md. (M)

Johnson, Howard R. H., Assistant to Deputy Chief, Operations, Air Photographic & Charting Service, 3701 North Broad St., Philadelphia, Pa. (A)

Johnston, Capt. Clint, Chief, Motion Picture & Video Production Division, Air Photographic & Charting Service, U.S. Air Force, 3701 N. Broad St., Philadelphia 40, Pa. (A)

Kaplan, Fred M., Geo. W. Colburn Laboratory, Inc. **Mail:** 6508 Rockwell, Chicago 45, Ill. (A)

Lee, Harold V., President and Manager, Colorvision, Inc., 129 W. Alameda Ave., Burbank, Calif. (M)

Lewis, Jack, Owner, Jack Lewis Studios, 705 East Main St., Richmond 19, Va. (M)

Lohnes, Kenneth F., Cine Technician, Warner Brothers Studio. **Mail:** 4604 Cahuenga Blvd., North Hollywood, Calif. (A)

Mack, Donald, TV Sales Manager, Production Assistant, Filmack Corp. **Mail:** 8626 Prairie Rd., Skokie, Ill. (M)

Oldershaw, Malcolm J., Consulting Engineer, Canadian Marconi Co., Ltd., 2442 Trenton Ave., Mount Royal, Quebec, Canada. (A)

Ottemiller, William H., Jr., Division Manager, Quality Control, Television Picture Tube Division, Sylvania Electric Products, Inc. **Mail:** R.D. #1, Seneca Falls, N.Y. (M)

Pike, Howland, District Manager, Ansco Division, General Aniline & Film Corp. **Mail:** 7125 Maple Ave., Takoma Park 12, Md. (M)

Powis, Chauncey G., TV Engineer, KDYL-TV. **Mail:** 59½ Hillside Ave., Salt Lake City, Utah. (A)

Rowley, Basil G. H., Technical Representative, Marconi's Wireless Telegraph Co., Ltd., 23-25 Beaver St., New York 4, N.Y. (A)

Sandwick, Luther M., Vice-President, Wilcox-Gay Corp., Charlotte, Mich. (M)

Sproul, Thomas G., Film Technician, Consolidated Film Industries. **Mail:** 4461 Morse Ave., North Hollywood, Calif. (A)

CHANGES IN GRADE

Bury, John L., Jr., (S) to (A)

Gausman, Harvey E., (A) to (M)

MacDonald, Joseph W., (S) to (A)

Wicker, L. P., (A) to (M)

SMPTE Officers and Committees: The roster of Society Officers and the Committee Chairmen and Members were published in the April *Journal*.

Chemical Corner

Edited by Irving M. Ewig for the Society's Laboratory Practice Committee. Suggestions should be sent to Society headquarters marked for the attention of Mr. Ewig. Neither the Society nor the Editor assumes any responsibility for the validity of the statements contained in this column. They are intended as suggestions for further investigation by interested persons.

Foam Prevention Tributyl phosphate has good antifoaming properties and in addition is colorless and odorless. This product is marketed by Apex Division of Food Machinery and Chemical Corp., Niro, W. Va.

Substitute for Metol *British Kinematography* has an article in the February 1952 issue (vol. 20, no. 2) describing a substitute for metol. It is 1-phenyl 3-pyrazolidene. It is white and odorless; and persons sensitive to metol poisoning are reported unaffected by this so-called Phenidone. Like metol it is sensitive to pH and is soft working when used alone. In combination with hydroquinone it gives a more rapid, less grainy image and produces less fog. It also yields a high contrast with hydroquinone and has a lower exhaustion rate. It is possible to match a metol-hydroquinone developer with a phenidone-hydroquinone developer.

Construction of Water Purifier An interesting article, "Pure water for your darkroom," in *American Photography*, (vol. 45, 341–346, June 1951), by H. F. Walton, describes a method for constructing a water-purification, ion-exchange unit. All that is required is some laboratory glassware and commercial resins.

Try It Before You Buy It A method for rapid identification of nickel alloys, stainless steels, etc., might be of value in the motion picture laboratory where the question of materials of construction of processing equipment often comes up. Such a quick test procedure has been described in a pamphlet by Henry B. Lee of Eastman Kodak and published as Special Technical Bulletin #98 by the American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa. The metals or groups of metals for which methods of testing are described are nickel, monel metal, inconel, stainless steel #316, other chrome nickel, nickel stainless steels, straight chromium stainless steels as a class, etc. All the requirements for testing are seven common chemicals, a stirring rod, a medicine dropper, a porcelain spot plate and an abrasive cloth.

Tank Cleaning Advice L. B. Russell Chemicals, Inc., of 60 Orange St., Bloomfield, N.J., markets a chemical preparation called "Wizz" which is used for cleaning developing tanks. Reported safe to handle, noncorrosive and useful with any type of material, it is dissolved in water. The solution is kept overnight in the developer tank which is then washed out thoroughly to leave the tank free of chemical deposit and crustation. Periodic treatment of developer tanks will add to uniformity of the developer and lengthen its life, eliminate dirt problems and generally improve processing.

Film Processing Chemistry A series of articles by various authorities dealing with some fundamental chemistry of film processing appeared in *British Kinematography*, vol. 20, no. 2, Feb. 1952. One of these articles discusses the various chemical constituents of a developer and their roles; the chemical reactions of a developer and the products formed. The matter of the dependence of the rate of replenishment on the amount of bromide that can be tolerated in the developer is discussed. It is also pointed out that the work of development is performed by metol while hydroquinone serves to reverse the oxidized metol back to its original functional state and thereby becomes oxidized itself. Therefore, the maintenance of the metol concentration in the developer is easy compared to that of hydroquinone. Some suggestions about electrolytic recovery of silver and the regeneration of hypo are also discussed.

Testing the Exhaustion of a Fixing Bath L. G. Sandys presents his views about how to increase the efficiency of fixing baths and methods of testing in an article, "Efficiency and conservation of fixing baths," published in *The British Journal of Photography*, Vol. 98, pp. 662–3, Dec. 1951. If a yellow precipitate persists upon the addition of a 4% potassium iodide solution to ten parts of the fixer, it is exhausted. This can be confirmed by agitation with a paddle of some kind and if a lasting froth develops it indicates that the bath is spent.

Temperature Control for Film Processing Solutions U.S. Patent #2,584,294 assigned to Remington Rand describes a procedure for isolating the developer and fixer sections of a processing machine by a compartment and circulating heated air from the drying compartment through this chamber.

Filter-Aid Aid During the present strike at Johns Manville, users of their Celite filter aids find themselves in a difficult situation. Perhaps the Brown Company of Berlin, N.H., have a solution to this problem with their "Solka-floc" which they claim (1) prevents "leak through" in the filtration process, (2) enables high flow rates, (3) enables controlled porosity in the filter cake and (4) reduces labor cost by diminishing the number of times filter presses have to be cleaned. The general sales office is at 150 Causeway St., Boston, Mass.

New Method of Rust Prevention VPI (Vapor Phase Inhibitor) is chemically known as dicyclohexyl ammonium nitrate and is manufactured commercially by Monsanto Chemical Company. By vaporizing and allowing it to deposit on the product, it is reported to prevent corrosion. It may be used by impregnating paper and lining a drawer with this paper. This will prevent corrosion of anything kept in this drawer. However, its methods of application are numerous. It is nonflammable and will reach areas where usual corrosion preventatives cannot be applied. One gram of VPI provides protection for one cubic foot of metal if properly wrapped to prevent loss of vapor.

Meetings

American Society of Photogrammetry, Annual Meeting, Jan. 14–16, Shoreham Hotel, Washington, D. C.

American Institute of Electrical Engineers (Symposium on the Science of Music and Its Reproduction — 3d Lecture), Jan. 15, Engineering Societies Bldg., New York, N. Y.

Society of Motion Picture and Television Engineers, Southwest Subsection Meeting, Jan. 16, Dallas, Tex.

American Institute of Electrical Engineers, Winter General Meeting, Jan. 19–23, New York, N. Y.

American Physical Society, Annual Meeting, Jan. 22–24, Cambridge, Mass.

Institute of Radio Engineers Conference and Electronics Show, 5th Annual Southwestern Conference and Show, Feb. 5–7, San Antonio, Tex.

American Institute of Electrical Engineers (Symposium on the Science of Music and Its Reproduction — 4th Lecture), Feb. 20, Engineering Societies Bldg., New York, N. Y.

National Electrical Manufacturers Association, Mar. 9–12, Edgewater Beach Hotel, Chicago, Ill.

Society of Motion Picture and Television Engineers, Southwest Subsection Meeting Mar. 16, Fort Worth, Tex.

Inter-Society Color Council, Annual Meeting, Mar. 18, Hotel Statler, New York, N. Y.

Optical Society of America, Mar. 19–21, Hotel Statler, New York, N.Y.

American Physical Society, Joint Meeting with APS Southeastern Section, Mar. 26–28, Duke University, Durham, N.C.

American Physical Society, Apr. 30–May 2, Washington, D.C.

Acoustical Society of America, May 7–9, Hotel Warwick, Philadelphia, Pa.

Society of Motion Picture and Television Engineers, Southwest Subsection Meeting, May 20, Dallas, Tex.

American Physical Society, June 18–20, Rochester, N.Y.

American Institute of Electrical Engineers, Summer General Meeting, June 29–July 3, Atlantic City, N.J.

Biological Photographic Association, 23d Annual Meeting, Aug. 31–Sept. 3, Hotel Statler, Los Angeles, Calif.

The Royal Photographic Society's Centenary, International Conference on the Science and Applications of Photography, Sept. 19–25, London, England

Theatre Equipment and Supply Manufacturers' Association Convention (in conjunction with Theatre Equipment Dealers' Association and Theatre Owners of America), Oct. 31–Nov. 4, Conrad Hilton Hotel, Chicago, Ill.

Theatre Owners of America, Annual Convention and Trade Show, Nov. 1–5, Chicago, Ill.

National Electrical Manufacturers Association, Nov. 9–12, Haddon Hall Hotel, Atlantic City, N.J.

Employment Service

Positions Wanted

Audio-Visual School of Education Graduate: M.A., Audio-Visual Education, New York University. Sound background in personnel and contact work, attractive, single, personable. Prefer position New York or New Jersey area. Spent 3 years abroad, civilian, Special Services Director. Miss Fredericka Appleby, 810 Broadway, Newark, N.J. HUmboldt 5-4582.

TV Producer-Director: Formerly Chief of Production in Army's first mobile TV system, experience in writing-directing high-speed, low-cost instructional productions; TV producer-director, KRON-TV San Francisco, five shows weekly. Desire connection in educational TV, preferably employing kinescope technique; married; prefer West Coast, but willing to travel; résumé, script samples, pictures of work — on request. Robert Lownsbery, 1116 E. Claremont St., Pasadena 6, Calif.

Research, field engineering, manufacturing opportunity for B.S. Electrical Engineering candidate, Jan. 1953; Scholarship student, M.I.T.; studied in Germany, 1945–1950. Languages: German, Polish, Russian and English. Some radio shop experience; also M.I.T. Library and Engineering Dept. Single, no dependents; Military Status, 5A (over 26). Prefer location in East. Joseph Liebermann, 513 Beacon St., Boston, Mass.

Position Available

Wanted: Young engineer, mechanical or electrical deg; with liking for fine machinery and creating it, some experience in mechanical design and some knowledge of optics or electronics; for work on development of new products; applications held in full confidence. Send complete résume to Sherman Fairchild and Assoc., Rm 4628, 30 Rockefeller Plaza, New York, Attn. Mr. Fairbanks.

Appearance Technology may not be a new term but it is being pushed into the light by Richard S. Hunter who announces that he has formed Hunter Associates Laboratory, 5421 Brier Ridge Rd., Falls Church, Va., a consulting group devoted exclusively to appearance and related optical properties of materials — color, diffuse reflectance, gloss or luster, turbidity, haze, opacity and the like. Mr. Hunter, who has left the position of Chief Optical Engineer with the Henry A. Gardner Laboratory at Bethesda, Md., reports that his organization is equipped to test materials for either routine or special appearance properties and to design appearance-testing instruments.

Papers Presented at the Washington Convention, October 6–10

By Sessions

MONDAY AFTERNOON — Television Session

J. E. Hayes, Canadian Broadcasting Corp., Montreal, Canada, "Television Facilities of the Canadian Broadcasting Corporation."

R. D. Chipp, Du Mont Television Network, New York, "Film Projection Using Image Orthicon Cameras."

L. L. Pourciau, General Precision Laboratory, Inc., Pleasantville, N.Y., "Television Camera Equipment of Advanced Design."

W. E. Stewart, Radio Corporation of America, Engineering Products Division, Camden, N.J., "New Professional Television Projector."

MONDAY EVENING — Television Session

William H. Offenhauser, Jr., New Canaan, Conn., "Nomenclature for Motion Pictures and Television in the Society of Motion Picture and Television Engineers."

Pierre Mertz, Bell Telephone Laboratories, New York, "Influence of Echoes on Television Transmission."

A. V. Loughren, Hazeltine Corp., Little Neck, L.I., N.Y., "The Accomplishments and Recommendations of the National Television System Committee in the Field of Color Television."

TUESDAY MORNING — Television Session

Mary Ellen Widdop, RCA Victor Division, Camden, N.J., "A Review of Work on Dichroic Mirrors and Their Light-Dividing Characteristics."

Ralph E. Lovell, National Broadcasting Co., Hollywood, Calif., "Time-Zone Delay of Television Programs by Means of Kinescope Recording."

Ralph E. Lovell and Robert M. Fraser, National Broadcasting Co., Hollywood and New York, "Instrumentation and Sensitometry Employed in Kinescope Recording."

John S. Auld, Signal Corps Photo Center, Long Island City, N.Y., "Facilities and Employment of the Signal Corps Mobile Television System."

TUESDAY AFTERNOON — Television Session

Karl Freund, Photo Research Corp., Burbank, Calif., "Shooting Live Television Shows on Film."

Ferenz Fodor, Filmcraft Productions, Hollywood, Calif., "Filmcraft's Camera Control System."

TUESDAY EVENING — General Session

Leonard A. Herzig, Prestoseal Manufacturing Corp., Long Island City, N.Y., "Method and Apparatus for Splicing Motion Picture Safety Film Without the Use of Cements or Adhesives."

Gustav Jirouch, Cine-Television Equipment, Ltd., Kent, England, "The Robot Automatic Film Splicer."

R. Kingslake (Committee Chairman), Eastman Kodak Co., Rochester, N.Y., "Optics Committee Report."

E. H. Bowlds, E. H. Bowlds Engineering Co., Los Angeles, Calif., "An Animation Stand of New Design."

John A. Rodgers, Eastman Kodak Co., Rochester, N.Y., "Projector for 16mm Optical and Magnetic Sound."

Ann Hyer, Division of Audio-Visual Education, National Education Association, Washington, D.C., "Planning Classrooms for Use of Audio-Visual Materials."

WEDNESDAY MORNING (Concurrent Sessions)
———— Film Processing Session

Leonhard Katz and William F. Esthimer, Raytheon Manufacturing Co., Newton, Mass., "Further Experiments in High-Speed Processing Using Turbulent Fluids."

F. Dana Miller, Eastman Kodak Co., Rochester, N.Y., "Rapid Drying of Normally Processed Black-and-White Motion Picture Films."

Edward B. Krause and Joseph A. Tanney, S.O.S. Cinema Supply Corp., New York, "The Bridgamatic Developing Machine."

E. K. Carver (Committee Chairman), Eastman Kodak Co., Rochester, N.Y., "Film Dimensions Committee Report."

John Streiffert, Kodak Research Laboratories, Rochester, N.Y., "A Fast-Acting Exposure Control System for Color Motion Picture Printing."

A. A. Duryea, T. J. Gaski and L. Mansfield, Pathe Laboratories, Inc., New York, "Film Presentation of Various Productions on Eastman Negative-Positive Color Process."

———— High-Speed Photography Session

John H. Waddell, Wollensak Optical Co., Rochester, N.Y., "Introduction of the Symposium and History of High-Speed Photography."

Richard O. Painter (Vice-Chairman), General Motors Proving Ground, Milford, Mich., "High-Speed Photography Committee Report."

Norman F. Barnes, General Electric Co., Schenectady, N.Y., "Optical Techniques for Fluid Flow."

Major P. Naslin, French Laboratory of Armament, Paris, France, "Some Simple Electronic High-Speed Photographic and Cinematographic Devices."

R. M. Blunt, Institute of Industrial Research, University of Denver, Denver, Colo., "The Use of Photography in the Underground Explosion Test Program, 1951–1952."

WEDNESDAY NOON — High-Speed Photography Luncheon

A. C. Keller, Bell Telephone Laboratories, New York, Keynote Address, "The Economics of High-Speed Photography."

WEDNESDAY AFTERNOON — High-Speed Photography Session

Louis F. Ehrke, Westinghouse Electric Corp., Bloomfield, N.J., "History of Ultra High, Speed X-Ray Exposures and X-Ray Motion Pictures."

S. J. Jacobs, Naval Ordnance Laboratory, White Oak, Md., "Space-Time Resolution as a Criterion for Comparing Ultra-High-Speed Photographs."

Roger Wilkinson, Bell Telephone Laboratories, New York, and Harry Romig, Hughes Aircraft Co., Culver City, Calif., "Space-Time Relationships With Multiple Camera Installations."

H. Schardin, Laboratoire de Recherches, Weil Am Rhein, Baden, Germany, "The Development of High-Speed Photographic Techniques in Europe."

Morton Sultanoff, Terminal Ballistics Laboratory, Aberdeen Proving Ground, Md. "Photographic Instrumentation in the Study of Explosive Reactions."

THURSDAY MORNING — High-Speed Photography Session

Harold E. Bauer and Webster Blake, Douglas Aircraft Co., Santa Monica, Calif., "The Applications of Wide-Angle Optics to Moderately High-Speed Motion Picture Cameras."

J. S. Courtney-Pratt, University of Cambridge, Cambridge, England, "Two New Methods of High-Speed Photography."

H. W. Greenwood, Canadian Armament Research and Development Establishment, Ottawa, Canada, "Information Discussion of Image-Convertors and Other Ballistic Methods."

F. W. Bowditch, General Motors Corp., Detroit, "The Use of Motion Picture Photography for Combustion Research."

Amy E. Griffin and Elmer E. Green, U.S. Naval Ordnance Test Station, China Lake Calif., "Accuracy Limitations on the Use of High-Speed Metric Photography."

W. O. Johnson, E. I. du Pont de Nemours & Co., Wilmington, Del., "High-Speed Photography in the Chemical Industry."

THURSDAY AFTERNOON (Concurrent Sessions)
——— General Session

R. D. Bennett, Technical Director of the Naval Ordnance Laboratory, White Oak, Md., "The Naval Ordnance Laboratory."

J. S. Watson, Jr., and S. A. Weinberg, University of Rochester School of Medicine and Dentistry, Rochester, N.Y., "70mm Motion Picture Camera for X-Ray Motion Pictures."

W. W. Lozier (Committee Chairman), National Carbon Co., Fostoria, Ohio, "Screen Brightness Committee Report."

Armin J. Hill, Motion Picture Research Council, Hollywood, Calif., "A Simple Formula for Taking Stereoscopic Motion Pictures."

Armin J. Hill, Motion Picture Research Council, Hollywood, Calif., "A First-Order Approximation for the Mathematical Treatment of Diffusing Surfaces."

Allen Stimson and Edward H. Fee, General Electric Co., West Lynn, Mass., "Color and Reflectance of Human Flesh."

——— High-Speed Photography Session

Harold C. Barr, Sandia Corp., Albuquerque, N.M., "High-Speed Photographic Instrumentation in Field Tests."

Berlyn Brixner, Los Alamos Scientific Laboratory, Los Alamos, N.M., "High-Speed, Rotating-Mirror Frame Camera."

A. M. Erickson, Naval Ordnance Laboratory, White Oak, Md., "Photographic Instrumentation of Timing Systems."

H. Schardin, Weil Am Rhein, Baden, Germany, "High-Speed Spark Photography."

I. L. Stern and J. H. Foster, Material Laboratory, New York Naval Shipyard, Brooklyn, N.Y., "High-Speed Photographic Techniques for the Study of the Welding Arc."

Charles T. Lakin, U.S. Naval Ordnance Test Station, Inyokern, Calif., "The 70-mm Test Vehicle Recorder."

W. R. Stamp and R. P. Coghlan, Royal Naval Scientific Service, United Kingdom, "Growth and Decay of Light Measured Photographically From Flash Discharge Tubes."

W. D. Chesterman, Royal Naval Scientific Service, United Kingdom, "New Precision Rotating Prism High-Speed Motion Picture Camera."

W. D. Chesterman, Royal Naval Scientific Service, United Kingdom, "Further Developments in High-Speed Photography in England."

Carl G. Jennergren, Research Institute of National Defense, Stockholm, Sweden, "High-Speed Photography in Sweden."

THURSDAY EVENING (Current Sessions)

——— Symposium on 16mm Equipment Maintenance

Bernard A. Cousino, Cousino, Inc., Toledo, Ohio, "Equipment Maintenance — Key to Success."

Henry H. Wilson, Ampro Corp., Chicago, "Operation of a Manufacturer's Service Organization."

Fred Whitney, SMPTE, New York, and R. A. House, Film Recording Group, RCA Victor Division, Camden, N.J., "Test Films for 16mm Equipment Maintenance."

Thomas C. Sheehan, Visual Instruction Office, Washington Public Schools, Washington, D.C., "Maintaining Visual Education Equipment in a Large City School System."

O. T. Bright, Bell & Howell Co., Chicago, "Selection, Training and Equipping Field Service Stations for Repair of 16mm Projection Equipment."

Philip M. Cowett, Bureau of Ships, U.S. Navy Dept., Washington, D.C., "Navy Maintenance of 16mm Projection Equipment."

——— High-Speed Photography Session

Karl W. Maier, Springfield Armory, Springfield, Mass., "A Procedure for Complete Analysis of High-Speed Motion Picture Data."

C. David Miller and Arthur Scharf, Battelle Memorial Institute, Columbus, Ohio, "An Isotransport Camera for 100,000 Frames per Second."

Robert D. Shoberg, Army Ordnance Corp., White Sands Proving Ground, Las Cruces, N.M., "High-Speed Instrumentation of Guided Missiles."

Kenneth Shaftan, J. A. Maurer, Inc., Long Island City, N.Y., "Progress in Photographic Instrumentation in 1951."

FRIDAY MORNING (Concurrent Sessions)

——— Sound Recording and Reproduction

W. K. Grimwood and J. R. Horak, Kodak Research Laboratories, Rochester, N.Y., "Optimum Slit Height in Photographic Sound-Track Reproducers."

J. K. Hilliard (Committee Chairman), Altec Lansing Corp., Beverly Hills, Calif., "Sound Committee Report."

Robert Dressler and Albert Chesnes, Paramount Pictures Corp., New York, "Sound-on-Film Recording Using Electro-Optic Crystal Techniques."

John G. Frayne, Westrex Corp., Hollywood, Calif., and J. P. Livadary, Columbia Pictures Corp., Hollywood, Calif., "Dual Photomagnetic Intermediate Studio Recording."

Maxwell A. Kerr, Navy Dept., Bureau of Ships, Washington, D.C., "16mm Release-Print Inspection — Some Observations and Proposals."

———— High-Speed Photography Session

Joshua Fields, Louis Fields, Eleanor Gerlach and Myron Prinzmetal, Institute for Medical Research, Cedars of Lebanon Hospital, Los Angeles, "High-Speed Cine-Electrocardiography."

Willard E. Buck, Los Alamos Scientific Laboratory, Los Alamos, N.M., "Transient Pressure Recording With a High-Speed Interferometer Camera."

Floyd Stratton and Kurt Stehling, Bell Aircraft Co., Buffalo, N.Y., "Applications of High-Speed Photography in Rocket Motor Research."

Harry R. Clason, National Advisory Committee for Aeronautics, Langley Field, Va., "A Method of Lighting Large Fields for High-Speed Motion Picture Photography."

William P. Holloway, U.S. Naval Ordnance Test Station, Inyokern, Calif., "A Theodolite Method of Camera Calibration."

Earl Quinn, Eastman Kodak Co., Rochester, N.Y., "A Case History of a High-Speed Tapping Operation."

FRIDAY AFTERNOON (Concurrent Sessions)

———— Symposium on Magnetic Striping of Film

Edward Schmidt, Reeves Soundcraft Corp., Springdale, Conn., "Commercial Experiences With Magnastripe Production."

B. L. Kaspin, A. Roberts, H. Robbins and R. L. Powers, Bell & Howell Co., Chicago, "Magnetic Striping Techniques and Characteristics."

A. H. Persoon, Minnesota Mining and Manufacturing Co., St. Paul, Minn., "Magnetic Striping of Photographic Film by the Laminating Process."

Thomas R. Dedell, Eastman Kodak Co., Rochester, N.Y., "Magnetic Sound Tracks for Processed 16mm Motion Picture Film."

G. A. Del Valle and L. W. Ferber, RCA Victor Division, Camden, N.J., "Notes on Wear of Magnetic Heads."

Ernest W. Franck, Reeves Soundcraft Corp., Springdale, Conn., "A Study of Drop-Outs in Magnetic Film."

E. W. D'Arcy, De Vry Corp., Chicago, "Standardization Needs for 16mm Magnetic Sound."

———— High-Speed Photography Session

David C. Gilkeson and A. E. Turula, Wollensak Optical Co., Rochester, N.Y., "Optical Aids for High-Speed Photography."

Frederick P. Warrick, Frederick P. Warrick Co., Bloomfield Hills, Mich., "A High-Speed Recording Camera Featuring Constant Film Velocity and Large Film Capacity."

John H. Waddell, Wollensak Optical Co., Rochester, N.Y., "Full-Frame 35mm Fastax Camera."

M. Roganti, Wright-Patterson Air Force Base, Dayton, Ohio, "New Air Force Recording Camera."

Myron A. Bondelid, U.S. Naval Ordnance Test Station, Inyokern, Calif., "The M-45 Tracking Camera."

Charles A. Hulcher, Charles A. Hulcher Co., Hampton, Va., "70mm High-Speed Sequence Camera."

Binding of a Volume of Journals

THROUGH the cooperation of the Library Binding Institute, an organization of binderies which specializes in binding publications into volumes, arrangements have been made to give information and assistance to Society members who want to have their *Journals* bound. This work may be done in accordance with standards of materials and construction required for durability, service and accessibility by college, reference and public libraries. The American Library Association and the Library Binding Institute have cooperated in promulgating "Minimum Specifications for Class A Library Binding" based on research and production and performance experience.

A committee of the American Library Association has certified responsible and reliable library binderies which have proved able to meet these specifications. To obtain standard quality binding, simply request Class A binding at any certified bindery. In obtaining price quotations, state the three dimensions of the volume.

Names and addresses of certified binderies in your area are available from the Library Binding Institute, 501 Fifth Ave., New York 17, N.Y.

A library binder who specializes in binding volumes such as those of this *Journal*, and who has been selected as a capable binder, for instance, by the American Institute of Physics, is The Book Shop Bindery, 308 West Randolph St., Chicago 6, Ill.

Before sending copies to the bindery:

1. Check for missing issues and check each issue for defects, missing pages, etc. Be sure to include the volume index. (Beginning with Vol. 56, No. 6 of the *Journal* carries a Volume Title Page and Contents.)

2. Tie the six issues together carefully and package so that nothing is crumpled or torn.

3. Write out definite instructions giving your preferences on the following points:

a. Color of binding (one of the following standard colors should be selected: dark green, dark blue, black, brown or medium red).

b. Whether the paper covers are to be bound into the volume.

c. An exact copy of the text to be lettered in gold on the backbone. A common form is:

Journal — 1¾ in. from top
SMPTE [SMPE before 1950] — 2¼ in. from top
Vol. 00 — 4¼ in. from bottom
1900 — 3¾ in. from bottom

d. If you have had *Journals* bound before and want your set to match as closely as possible, send a previous volume as a sample. If you want an approximate match, send a "rubbing" of the lettering on a previous volume and indicate the color.

If satisfactory arrangements cannot be made, or if there is any difficulty, advise the Society office and steps will be taken in cooperation with the Library Binding Institute to assure you proper service.

As Part II of this issue, there is appended a Volume Title Page with Volume Contents to go at the front of the volume when bound, and the Volume Index to go at the back.

A microfilm edition of the *Journal* may also be obtained by members or subscribers by direct correspondence with University Microfilms, 313 North First St., Ann Arbor, Mich.

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40 West 40th Street, New York 18, N. Y., Tel. LOngacre 5-0172
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